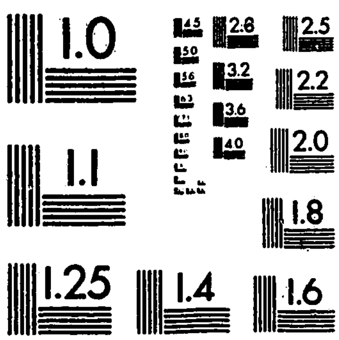
1



University of Alberta

MECHANICAL AND ELECTROTHERMAL DEBONDING: EFFECT ON CERAMIC VENEERS AND DENTAL PULP

by

C. TODD LEE-KNIGHT , BSPE, DMD ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
CLINICAL SCIENCES
(ORTHODONTICS)

FACULTY OF DENTISTRY

EDMONTON, ALBERTA
FALL 1995

National Library of Canada

Acquisitions and Bibliographic Services Branch

395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada

Direction des acquisitions et des services bibliographiques

395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

ISBN 0-612-06497-2

Canada

University of Alberta

LIBRARY RELEASE FORM

NAME OF AUTHOR: C. Todd Lee-Knight, B.S.P.E., D.M.D.

TITLE OF THESIS: Mechanical and Electrothermal Debonding: Effect on Ceramic Veneers and Dental Pulp.

DEGREE: Master of Science in Clinical Sciences (Orthodontics)

YEAR THIS DEGREE GRANTED: 1995

C. Todd Lee-Knight, B.S.P.E., D.M.D.

21 - 4403 Riverbend Road
Edmonton, Alberta
T6H 5S9

October 10, 1995

"There are always some who think it's brute strength. They tug and jerk and pull, and all they do is disturb the run of the boat. But rowing is like ballet dancing -- if it's carried out properly, you can't see the work being done."

Frank Read, National Rowing Coach
1954 Commonwealth Games
1956, 1960 Olympic Games

"Ets-vous prêt...partez."

Federation International des Societes d'Aviron

University of Alberta

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled:

Mechanical and Electrothermal Debonding: Effect on Ceramic Veneers and Dental Pulp

submitted by Christopher Todd Lee-Knight in partial fulfilment of the requirements for the degree of Master of Science in Clinical Sciences.

K.E. Glover, B.Sc., D.D.S., M.S.D., Supervisor

S.G. Wylie, B.D.Sc., M.D. Sc.

P.W. Major, D.D.S., M.Sc.

M.G. Faulkner, B.Sc., M.Sc., Ph.D., P.Eng.

Date: June 22, 1995

Dedication

This work is dedicated to the people whom I hold most dearly -- those who have influenced my education over a period of many years and who hold special meaning in my life:

To my mother and father, Ruth and Jack, who provided support, and love throughout my life; who offered guidance; who allowed discovery; who taught me understanding; and who provided me with a lifetime of opportunity.

To the memory of my sister, Lorie, who taught me to seek beyond the attainable and to make it so.

To my wife, Kim, and my children, Luke and Logan, who allowed me live the dream and make it all happen! To them I owe everything.

Abstract

This study evaluated the ability of three orthodontic debonding techniques to remove brackets from ceramic veneers without creating veneer damage. It also evaluated the intra-pulpal temperature changes produced by electrothermal debonding. A sample of 96 extracted maxillary first bicuspids were prepared and restored with Mirage™ ceramic veneers. Veneer buccal surfaces were etched with 2.5% hydrofluoric acid prior to silane application and bracket bonding. Specimens were thermocycled prior to debonding. All debonded specimens were examined under x20 magnification for veneer damage. Removal of metal brackets via electrothermal debonding produced ceramic damage in 13% of cases, and elevated temperatures beyond the threshold of irreversible pulpal damage (5.5°C) in 46% of cases. Howe plier and LODI bracket removal are associated with ceramic damage incidence of 21% and 35% respectively. Results suggest that electrothermal debonding provides predictable debonding of ceramic brackets with no veneer damage and minimal risk to the pulp.

Acknowledgments

I would like to express my gratitude to a number of individuals who were of great assistance during my period of study at the University of Alberta.

Dr. Ken Glover and Dr. Paul Major offered support and guidance throughout the entire program, resulting in a positive learning experience. As supervisors of my thesis project their input and direction was most appreciated.

Dr. Simon Wylie is to be thanked for his tireless clinical efforts, without which this project would not have been possible. His quest for clinical perfection is an example for others to follow and learn from.

I would like to thank each of the part-time clinical instructors who are such a vital part of making our clinical program what it is. It was an honor to study under and to be associated with all of these fine individuals, including: Dr. Subash Alimchandani, Dr. Bus Haryett, Dr. Michael Pawliuk, Dr. Ron Mullen, and Dr. Nancy Weaver. I gleaned from each of their perspectives, based on experience from the real world of patient management and treatment mechanics.

The clinical staff were second to none for their willingness to help in what can be a very hectic clinic. I would like to thank Maureen Dmytrash, Brigitt Klemp and Carol Gervais for creating an enjoyable atmousphere, for putting up with my jokes, and for their never-ending assistance in serving our patients. A special thanks goes to Margaret (Margaritaville) McGillicudy who always came through in the crunch with the lab work needed "for later today".

Despite the long hours, late nights, and lost weekends for two and a half years, life as a Graduate Student has been wonderful! The strong friendships that I have made with my fellow Orthodontic Residents shall last a life-time. A special thanks goes to my 'big brother', Peter Gaffey who epitomized and encouraged motivation, and to my 'side kick' Ritchie Mah, whose continuous attention to detail has been inspiring. My classmate, Jian Mao, has been wonderful to work with and share not only ideas, but time with. I hope that I have been able to pass on as much as I have gained from those before me to the next class members, Gail Burke and Lesley Williams, who are now well on their way.

Perhaps my greatest thanks should be extended to my many wonderful patients, without whom my clinical training would not have been possible!

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One

General Introduction
and
Literature Review

1.1 INTRODUCTION:

Patients with excessive overjet have a significantly greater risk of receiving a traumatic insult to the dentition. Lee-Knight *et al.*[1] and Bell *et al*[2]. reported that the age group at greatest risk of dental injury was between six and twelve years, the same group most often seeking orthodontic treatment. Proffit[3] stated that there is about one chance in three that a child with an untreated Class II malocclusion will experience significant trauma to upper incisors. This often results in crown/root fracture and/or pulpal devitalization. Alexander[4] reported that maxillary anterior teeth are susceptible to injury in most Class II Division 1 cases because of their protrusion. Of these injuries, approximately one-third are a result of participation in contact sports, with the remainder being a direct result of other trauma. Typical injuries involve fractured teeth, requiring placement of a permanent restoration. The restoration of choice often will be a ceramic veneer, covering the entire labial surface of the clinical crown and replacing missing tooth structure. Subsequent orthodontic treatment has traditionally had problems in bonding brackets to ceramic surfaces. The traditional method of dealing with such situations involving crowns was to place a fitted band around the restoration. This was not only time consuming and unacceptable to patients, but required interproximal band space closure, extending treatment time. However, advances in bonding materials have introduced organosilane surface primers making possible clinically acceptable and predictable bonds to ceramic without mechanical preparation.[5] Eliminating mechanical preparation of the surface reduces the risk of microcrack formation within ceramic veneers. However, achieving satisfactory bond strengths for orthodontic treatment may result in ceramic fracture upon debonding.

Although many previous studies[5-15] have examined bond strength and debonding techniques involving orthodontic brackets and ceramic fused to metal crowns or fixed bridges, few have studied the effect on ceramic veneers. The purpose of this study was to evaluate and compare the differences in debonding orthodontic brackets from ceramic veneers among three techniques: Howe pliers, lift off debonding instrument (LODI)(3M Unitek, Monrovia CA), and electrothermal debonder (ETD™)("A" Company, San Diego CA). Of particular interest will be veneer damage from three debonding techniques and pulpal temperature changes due to ETD™.

1.2 STATEMENT OF THE PROBLEM:

Ceramic veneers are fabricated to a maximum thickness of 0.5 mm. Although orthodontists would like to obtain a reliable bond to ceramic veneers during the treatment phase, they (along with the patient) would like to ensure that bracket removal can be accomplished safely without veneer damage. Practitioner and patient satisfaction is reduced considerably in the event that a ceramic veneer is damaged during bracket removal. Practitioners must be aware of the potential thermal damage of pulpal tissue when electrothermal debonding techniques are used.

1.3 RESEARCH QUESTIONS:

Research questions to be investigated:

Does mechanical bracket removal from ceramic veneers result in veneer damage?

Does ETD™ of orthodontic brackets from ceramic veneers result in veneer damage?

Does ETD™ of orthodontic brackets produce less veneer damage than mechanical removal?

What temperature increase is the pulpal tissue exposed to during electrothermal debonding of orthodontic brackets from ceramic veneers ?

1.4 HYPOTHESES:

H1: There is no difference in the incidence of veneer damage resulting from the debonding techniques used for ceramic or metal brackets.

H2: There is no difference between the intrapulpal temperature produced by electrothermal debonding metal or ceramic brackets.

1.5 LITERATURE REVIEW:

1.5.1 Ceramic Veneers

Indications

Ceramic veneers have been used as restorations of choice in many clinical situations over the past decade.[16] Where good tooth structure remains but some color, contour or incisal length changes are desired, the ceramic laminate veneer is an outstanding esthetic and restorative choice.[17] Indications for placement of ceramic veneers include: discoloration, enamel defects, diastemata, malpositioned teeth, malocclusion, poor restorations, aging, wear patterns, and agenesis of lateral incisors treated by cuspid substitution.[16] Veneers may be in place for any number of reasons when patients present for orthodontic treatment. Esthetics provided by these biocompatible restorations are excellent, as are strength properties. Although the veneer itself is rather fragile, once luted to enamel it has high tensile and shear strengths. Both patient and practitioner find them appealing because of the conservative nature of tooth preparation required by these restorations.

Tooth Preparation

Optimal conditions would permit veneer placement with no tooth preparation while maintaining good esthetics and without compromising periodontal conditions. However, since this cannot be achieved, a minimum amount of enamel reduction is required. A standardized method of tooth preparation for veneers should be followed to achieve optimal results. The rationale for enamel preparation has been outlined as follows:

- to provide adequate dimension of space for ceramic, opaquing and resin materials
- to provide for a path of insertion
- to provide a definite seat to help position the laminate during placement
- to prepare a receptive enamel surface for etching and bonding the laminate
- to facilitate sulcular margin placement in severely discolored teeth.[16]

Sheets and Taniguchi[18] recommended routine enamel reduction in preparation for ceramic veneers. However, they recommend that only the margins of the preparation be polished and that all internal portions be left roughened for maximum bond strength. This may include depth cutters of 0.3 mm or 0.5 mm (LVS-1 or LVS-2, Brasseler Laminate Veneer system Set 4151, Brasseler Canada, Montreal, PQ.), which is adequate to allow for bulk of restorative material while staying within the enamel layer. A chamfer margin is generally accepted as appropriate to ensure adequate marginal ceramic thickness, and is obtained with a two-grit diamond stone (LVS-3 or LVS-4). Margins of the preparation are polished with a 12-fluted bullet-shaped finishing bur (Brasseler H283K016).

Technical fabrication of accurately fitting veneers is extremely difficult in situations where a definite seat has not been established by extending the restoration over the incisal edge or where ceramic thickness measures less than 0.3 mm. In a photoelastic study of veneer tooth-preparation designs, Highton *et al.* reported incisal coverage of 0.5 mm results in lower concentrations of stress. This incisal coverage was also advocated in a study reviewed by Stacey.[19]

Andreasen *et al.*[20] described a method of restoring-crown fractured incisors with ceramic laminate veneers. These incisors were restored following one of three conditions:

1) after having the crown fragment reattached with dentin bonding agent; 2) after a composite build-up; or 3) no treatment. Their finding was that all three methods exceeded the fracture strength of intact incisors. The greatest fracture resistance occurred when a Dicor laminate veneer alone was used to restore the fractured incisal edge.

Key to obtaining an accurately fitting veneer is a satisfactory impression. Final impressions should be obtained by using two viscosities of impression material held in a rigid custom tray for greatest accuracy.[18] The light bodied material is syringed into the sulcus and over the entire preparation. Heavy bodied material is then transferred to the mouth in the stock tray and placed over the light bodied material and prepared tooth/teeth. The impression material should have a high tensile strength as well as accuracy.[16]

Tooth preparation for ceramic veneers is conservative enough that temporary restorations are very rarely, if ever required.

Veneer Fabrication

Two contemporary laboratory techniques for fabrication of ceramic veneers include the refractory investment technique, and the platinum foil technique. Sheets and Taniguchi[21] conclude that a multi-die (refractory investment) technique produces the best result. Multiple restorative technique completion is possible on one master cast. Marginal accuracy is improved due to better visibility and access during fabrication, and it is easier to establish suitable crown contours. Ceramic firing time is reduced and it allows direct adjustment of fired ceramic to a desirable contour. Sorensen *et al.*[22] reported improved vertical marginal adaptation with platinum foil compared with the refractory die technique. Both techniques resulted in overcontoured veneers, with those produced by refractory die technique being much more so. The gap discrepancy with the refractory die technique was attributed to marginal abrasion from the aluminum oxide used to remove the refractory die material from the ceramic veneer. Microleakage at the tooth-composite resin interface was universal, while that at the ceramic-composite resin interface was negligible. The clinical quality of ceramic veneers placed by general practitioners has been found to be satisfactory in 99% of cases, and excellent in one third of those.[23]

Garber[16] has reported that finishing and contouring is accomplished with a series of medium and fine grit diamonds to gain optimal shape and contour prior to glazing. The glazing process seals any microporosities and achieves a more natural luster.

Guidelines for Bonding Veneers

A standardized protocol for tooth conditioning has been previously published, and is followed by most bonding studies.[24] Exposed enamel receives a 15-second rubber cup prophylaxis followed by rinsing and drying with water and air spray. Teeth are etched with a 37% orthophosphoric acid gel for 15 seconds, rinsed for 30-seconds, and then dried with an air syringe. Any tooth that did not display a uniformly etched surface is re-etched.

A low viscosity microfilled composite resin is the bond material of choice since it allows complete seating of the veneer, and produces a stable, highly polishable, stain-resistant margin.[18] Once fully seated the veneer is exposed to polymerizing light. This is accomplished in segments, curing each labial quadrant and then the center of the labial surface. Final polymerization occurs from the incisal and interproximal aspects of the lingual surface. Dual cure materials assure a complete polymerization process but may slightly discolor with time.[18] Nathanson[16a] noted that complete polymerization of the composite resin is another essential requirement for obtaining a good bond between the tooth and ceramic. Tay *et al*[25]. found that running a fine sable brush moistened with bonding resin over the margins removes excess luting resin, seals the gap, and produces a smoother more polishable margin. Minimal finishing is required if margins fit precisely and excess bonding material has been thoroughly cleaned away.

1.5.2 Orthodontic Bonding

Buonocore[26] introduced the concept of acid etching with orthophosphoric acid, producing an alteration of the enamel surface to which dental resins could adhere. Resins evolved from cyanoacrylate, epoxy, and acrylic to bis-GMA, and finally the composites of today. These include two-paste, powder-liquid, one-paste (no-mix), light-cured systems. Contemporary use of acid etching in restorative dentistry includes conditioning of both enamel and ceramic surfaces. A common ceramic etchant is hydrofluoric acid in gel form, ranging in concentration between 2.5-9.6%. Zachrisson and Buyukyilmaz[13] identify that etchant creates microporosities on the ceramic surface that achieve a mechanical interlock with the composite resin. Etched ceramic has a frosted appearance similar to that of etched enamel. They suggest that optimal bonding of orthodontic brackets to ceramic surfaces may be obtained by deglazing the ceramic surface by sandblasting with 50 µm aluminum oxide for 2-4 seconds, followed by etching with 9.6% HF acid gel for 2 minutes. Two or three coats of a silane ceramic primer are applied prior to bonding with a highly filled bis-GMA.

Stangel *et al.*[27] described techniques relying on a hydrolyzed silane coupling agent to bond orthodontic brackets to ceramic restorations. Silane products are commercially available in both hydrolyzed and non-hydrolyzed states. The process of hydrolysis activates the silane and prepares it for chemical and mechanical interaction with the ceramic surface. With a non-hydrolyzed silane agent (Ormco® Ceramic Primer), etchant (phosphoric acid from the composite bonding kit) activates the silane, hydrolyzing it to interact with the ceramic surface.

Hydrolyzed silane systems (Scotchprime®) are less stable in the container and shelf life is shorter. If used after it has become inert, it may result in bond failures. This system involves the application of three layers of hydrolysed silane on previously etched, washed, and dried ceramic for approximately two minutes. Organosilane will initially hydrogen bond to the ceramic mineral surface prior to developing a permanent covalent oxane bond. A non-filled resin primer is applied to the ceramic surface over the silane layer. Filled composite resin is applied to the bracket base and positioned.

1.5.3 Dental Ceramic

Ceramic Veneers

Nathanson[16a] noted that processed dental ceramic has a high compressive strength, and is completely non-ductile and brittle. Inherent in the manufacturing process of dental ceramic is the production of surface irregularities and subsequent reduction in tensile strength. These surface irregularities, though microscopic in size, cause stress concentrations. Defective ceramic subjected to tensile stresses may develop larger cracks by the mechanism of crack propagation. This may ultimately lead to failure as a brittle fracture.

Although research has evaluated bonding orthodontic attachments to ceramic denture teeth and crowns, the effectiveness of bonding to thin ceramic veneers has received minimal attention.[8] The composition of dental ceramic differs between restoration designs.[10] Denture teeth are composed of high-fusing dental porcelains, making them much more brittle and of lower strength than the alumina-reinforced ceramics employed for veneers.[28] This places the results of bonding studies using denture teeth in question.

A common problem encountered in bonding to ceramic has been the development of inadequate bond strength.[29] Ceramics used in restorative dentistry are a mixture of fine particles of quartz and feldspar. Quartz provides strength and acts as a filler within a matrix of feldspar. Calamia *et al.*[30] concluded that the feldspar type of ceramic produces bond strengths much greater than the aluminous type. Bailey demonstrated that the chemical nature of dental ceramic is modified by hydration, resulting in lower bond strengths than non-hydrated samples.

Kao and Johnston[14] stated that retention and mechanical support of ceramic veneers is a direct function of how well the resin penetrates the ceramic etch. Any reduction in retentive "tags" of the bonding resin may reduce both the bond of veneer to etched enamel and the strengthening effect of veneer by the underlying resin. Based on the findings of Griffith, they proposed that veneer fractures arise from fine flaws in the surface of the material. These flaws may be accentuated during handling of the veneer in the laboratory or at clinical try-in and cementation. Thermocycling may also introduce flaws due to differing coefficients of thermal expansion for ceramic, resin, and enamel. Although such flaws may not be detectable clinically, they may become evident when stresses are applied, such as during debonding. High-alumina ceramic (Vita®, Bad Säckingen, Germany) is particularly susceptible to fracturing if its surface has been roughened, as compared to the feldspathic ceramic veneers.[14]

Ceramic Brackets

Eliades *et al.*[31] presented a polarized-light photomicrograph of a Starfire® ("A" Company, San Diego CA) bracket base to illustrate the appearance of (Griffith) flaws arising from the manufacturing process. Critical stresses arise locally at the surface flaws when ceramic is subjected to sufficiently high loading which exceeds the cohesive strength of aluminum oxide.

Birnie.[32] noted that ceramic material used in orthodontic brackets is alumina, either in polycrystalline or monocrystalline form.[98] The advantages of using alumina for orthodontic brackets is that appearance is very good, and is both hard and strong. The disadvantages include its lack of ductility and its expense and difficulty related to manufacturing.

Monocrystalline brackets are machined from extrusions of synthetic sapphire. Polycrystalline alumina brackets, by contrast, are made by injection moulding submicron-sized particles of alumina suspended in a resin, sintering them (to fuse the alumina) and machining to produce the final bracket. Difficulties in the use of ceramic brackets arise from their brittleness and their hardness, producing either enamel cracks or fractures when debonded.

1.5.4 Etching (Effectiveness)

Etching the veneer inner surface provides not only retention, but also reinforcement. Bonding resin provides considerable retention and simultaneously protects ceramic from cracking and fracturing under tensile stresses. Polymerization shrinkage of resin (a property inherent in most polymers) stresses the thin ceramic in a direction that reduces the chance of crack formation and propagation.[16] Early ceramic etching consisted of either a 15-minute etch with a 10% hydrofluoric acid or a 20-minute etch with a commercial preparation (primarily diluted hydrofluoric acid).[33] More recent methods have revealed that the most retentive pattern results from refractory processed ceramic treated for 2.5 minutes of etching with Stripit solution (Keystone, Philadelphia, Pa.). Stripit is a commercial HF acid substitute, consisting of HF/sulfuric acid in water (30%). Hsu *et al.*[34] found the combination of ceramic etching and silane has a cumulative effect, producing bond strengths of 24.14 MPa. By SEM examination of the ceramic/resin interface, Nathanson[16a] found the existence of a gap at the interface when ceramic was not etched. This is best explained by the polymerization contraction of resin. Silane treatment caused a narrowing of the gap, apparently because of improved chemical attraction between the silanol group and the ceramic. In cases where ceramic was etched, the silane-treated groups were observed to have no gap present, and resin seemed to have filled all ceramic defects. Calamia *et al.*[30] found that ceramic etch time producing the greatest bond strengths was 2.5 minutes, and that feldspar type ceramic bonds were considerably stronger than aluminous type. Results showed a composite-ceramic bond stronger than typical composite-enamel bond strengths.

1.5.5 Bonding to Ceramic

As demand for adult orthodontic treatment increases and the popularity of esthetic dentistry expands, orthodontists are more likely to be faced with the problem of placing orthodontic appliances on teeth previously restored with resin and ceramic fixed prostheses, including crowns, bridges, and veneers.[8] As a result, orthodontists need to acquire more knowledge about bonding to non-enamel surfaces. In the past these teeth have been managed orthodontically either by banding, or placement of a temporary acrylic restoration since glazed ceramic surfaces were not amenable to resin penetration.[6,9] Although these compromised methods are satisfactory for crowns, they may be inappropriate for use with restorations as thin as ceramic veneers.

Deglazing

When ceramic glaze is removed and silane primer applied, it has been demonstrated that average debonding forces are comparable to that of acid-etched enamel bond at 24 hours.[8] Ghassemi-Tary[35] suggested deglazing be accomplished with a sandpaper disk. Solomon *et al.*[36] reported deglazing methods as including sandblasting, roughening with a diamond, etching with 9.6% hydrofluoric acid, and a combination of the latter two methods. The most effective treatment for ceramic repair was the combination of mechanical and chemical means. Highton *et al.*[37] reported that abrasive coarseness has an effect on the degree of retention, with a coarse diamond yielding the best results. However, for orthodontic application, removal of the ceramic glaze may lead to greater damage to ceramic during the debonding procedure. Wood[7] found that bond strength increases significantly by roughening the ceramic surface before bonding, adding ceramic primers, and using highly filled resins. However, these processes also caused a progressively greater risk of ceramic fracture during debonding. Thus, mechanical roughening appears unfavourable since it induces microfractures in the ceramic that render it more prone to fracturing upon debonding. Eustaquio *et al.*[10] also found that deglazed specimens appear to be more vulnerable to ceramic fracture. This was attributed to increased mechanical retention and surface area for adhesion or microcracks introduced when grinding off the glaze. Nicholls[12] reported that increasing acid etch time of ceramic resulted in a proportional increase in bond strength. Zachrisson and Buyukyilmaz[13] reported that etching of glazed ceramic produces less prominent micromechanical patterns than etching of ceramic roughened by aluminum oxide sandblasting. However, intraoral sandblasting is preferable to grinding with a green stone, which could produce microcracks.

Nebbe and Stein[38] demonstrated that shear peel bond strength was greater for brackets bonded to glazed ceramic, and that ceramic fractures were associated with deglazed sample at a rate twice that of glazed samples (71% versus 36%).

Silane

Research into adhesive systems has made it possible to achieve direct bonding to surfaces such as ceramic with much more confidence of achieving clinical success. Wood *et al.*[7] found that the use of a ceramic primer before bonding with bis-GMA adhesives resulted in shear strengths comparable to those achieved with conventional acid-etch enamel bonding when the same resin was used (13.6 MPa). Clinically acceptable bond strengths of 6-8 MPa are now possible with the use of organosilanes, without mechanically removing the glaze (with rotary instrumentation) from the ceramic.[6] Hsu *et al.*[34] demonstrated that bond strengths were substantially increased by etching ceramic followed by application of silane bond agent. Stacey[19] found in a study of ceramic veneers that silane treatment of etched ceramic elevated the ceramic/composite resin cement bond strength 2.7 times over the non-silane treated samples. This difference was further magnified to sevenfold following a thermocycling process. Despite the predictable bond strengths of resin/silane to ceramic, it is ultimately necessary to remove orthodontic brackets from the teeth. The higher the mean shear bond strength, the greater the incidence of ceramic damage.[5]

Silane (gamma-methacryloxypropyl-trimethoxy silane) is a bifunctional molecule. One end is a hydrolysable, reactive silanol group that can react/bind tenaciously to an inorganic substrate (dental ceramic), while the organofunctioning groups of the molecule react with the adhesive (acrylic resins) and polymerizes, producing a cohesive bond with the resin material.[39] The portion of the silane molecule that is not adsorbed presents a surface that facilitates interaction with restorative material.[6,37]

Major *et al.*[5] discussed the latest generation of bond agents, including an organosilane, biphenyl dimethacrylate (BPDM) resin, and NTG-GMA bond accelerator. The combination of BPDM & NTG-GMA increases the wettability of ceramic and accelerates curing of the overlying composite resin. Organosilane initially forms weak hydrogen bonds to the mineral surface of ceramic, but over the first 24 hours bonds develop and stabilize. It is important to note that water can interfere with the ability of silanol to form an oxane linkage. In addition, resin must be able to set undisturbed to avoid weakening.

Eliades *et al.*[40,41] suggested that the mechanism of action for silane is due to activated silanol groups adhering to the hydration layer of alumina crystals via hydrogen bonding, while methacrylate groups react in a second step with the adhesive resin, forming covalent bonds. As a result, the propensity for primary bonding between the silane molecule and the adhesives is substantially increased. In their study of ceramic brackets bonded to enamel, the combination of micromechanical retention and silane treatment of the brackets produced the highest bond values, even after thermocycling.

The chemical bond formation between ceramic and resin is dependent on the occurrence of a series of events:

1/ hydrolysis of organosilane to form an organosilanol

2/ initial formation of oxane linkage

3/ condensation reaction to form permanent oxane bond.[5]

Nicholls[12] reported that the silane layer is susceptible to moisture contamination, thus a dry storage condition for veneers is required if a delay exists between silane application and cementation.

1.5.6 Bond Strength

Reynolds[41] classified the two major polymers used in direct bonding as i) acrylic resins, and ii) diacrylate resins. Acrylic resins consist of methyl methacrylate monomer and ultrafine polymer powder, and may be either filled or unfilled. Normal activation occurs by conventional tertiary amine-benzoyl peroxide curing. Although coefficients of thermal expansion for these materials may be ten times that of the tooth, the film thickness used to bond orthodontic brackets is so small that any resultant effect is minimized. Diacrylate resins (including) bis-GMA, combine acrylic's setting versatility and epoxy's strength and stability.

Joseph and Rossouw[42] found that brackets bonded with heavily macrofilled resin (Concise®) and those bonded with lighter microfilled resin (Heliosit®) produced a shear bond strength that is greater than that considered clinically acceptable. Viazis *et al.*[24] found no difference between the mean shear bond strengths of Concise (conventional chemical cure) and Transbond (light-cured). Ostertag *et al.*[43] found a trend toward increased bond strength with increasing filler concentration for bonded ceramic brackets. Inorganic fillers are added to bonding adhesives to reduce the coefficient of thermal expansion toward that of enamel (thus reducing shrinkage), and to improve flexural, tensile, and compressive strengths.[44,45] It has been found that bonding metal brackets with a highly filled resin (Phase II®) results in a shear strength approximately twice that of a lightly filled resin (Endur®).[7,46] This was independent of the ceramic surface preparation or bonding agent used. Kao *et al.*[8] determined that highly filled resin (Concise®) required 50% greater debond force than lightly filled resin (Unite®). Buzzitta *et al.*[47] reported similar findings with both plastic and ceramic brackets. Major *et al.*[5] found that Phase II® and Rely-a-Bond® were both effective when used with

Ormco® Ceramic Primer®, but especially effective with Scotchprime®. Klockowski *et al.*[48] observed a trend of deterioration in bond strength following thermocycling for Rely-A-Bond® compared to glass ionomer cements. However, Rely-A-Bond® provided the strongest bond with and without thermocycling. Although chemically cured macrofilled resins are reported to have higher bond strengths (more elastic) than light-cured microfilled resins (more brittle), results presented by Joseph and Rossouw[42] indicated similar mean shear bond strengths of the two groups for both stainless steel brackets (17.34 MPa and 17.80 MPa) and ceramic brackets (28.27 MPa and 24.25 MPa). Odegaard and Segner[49] found no statistical difference in bond strength of light- or chemical cured resins bonding ceramic brackets to enamel.

Knoll *et al.*[50] demonstrated in vitro that bond strengths for brackets bonded to anterior teeth were greater than for those bonded to posterior teeth. Although the investigators noted that the finding correlates with the clinical observation that posterior bonds have a greater rate of failure, it is due to greater masticatory forces in the posterior region of the mouth and the non-uniformity of the resin thickness between the enamel and bracket base for posterior teeth.

Coreil *et al.*[51] presented bonding agents containing solvents which were thought to improve polymerization of unfilled resin primer and result in increased bond strength. In theory, complete polymerization of resin primers was prevented by oxygen inhibition. However, clinically, the addition of these agents did not appear to affect bond strength.

Evans and Powers[52] recommended that a minimal and uniform thickness of resin cement be used to maximize bond strength of orthodontic attachments to teeth. Bond strength decreases as thickness increases due to a greater amount of thermal expansion, polymerization shrinkage, trapped volatiles, and imperfections.

1.5.7 Polymerization

Polymerization of light-activated resins under metal brackets by transillumination is successful since the tooth conducts visible light well. Ceramic brackets are translucent and permit passage of light through to the resin layer. Control over the rate of polymerization improves the accuracy of bracket positioning.[42] Once brackets are correctly positioned, excess composite material can be removed prior to light polymerization, since inadvertent bracket movement will not affect the bonding capacity of light cured resin.

Whitlock *et al.*[15] examined three types of cement in luting ceramic brackets to ceramic veneer restorations. They determined light-activated adhesives to have the greatest variability in shear bond strength, possibly attributed to a dissimilar transmission of light through the veneer as compared to a natural enamel surface. No-mix resins had the highest bond strength when used in conjunction with silane. However, all systems (two-paste, no-mix, and light activated) fell within the clinically acceptable range of 6-8 MPa shear strength.

1.5.8 Thermal Cycling

Shear bond strength of orthodontic brackets has been investigated in many previous reports.[6,24,27,42,46,48,50,53,54] In the majority of cases, shear bond strength has been determined with an Instron testing device (Instron Corporation, Canton, Mass.), applying a load to the occlusal margin of each bracket to the point of failure. Most investigators have used thermocycling as part of their experimental protocol in vitro, to simulate the thermal extremes of the oral cavity.[6,10,48,53,54]

Nelsen *et al.* estimated the limits of oral thermal tolerance to be 60°C and 4°C. Diaz-Arnold and Aquilino[54] reported that a statistically significant decrease in mean shear bond strength occurred with the addition of thermal stress introduced by thermocycling between 5-60°C. Newman *et al.* used only 100 cycles between 4°C and 60°C with one minute in each bath.[53] Peterson *et al.*[55] measured the temperature at the tooth surface when hot coffee (60°C) and ice water (0°C) were drunk alternately to be within a range of 45°C to 15°C. Klockowski *et al.*[48] subjected specimens to three thermally controlled streams of water maintained at 4-6°C, 36-38°C, and 53-55°C. One cycle lasted one minute and consisted of 15 seconds each at 36-38°C, 53-55°C, 36-38°C and 4-6°C, for a total of 1500 repetitions. In their conclusions, they suggested that future research should focus on the long-term effects of thermal stress by exposing specimens to longer periods of thermocycling. Kao and Johnston[14] used a regimen of a 1000 one-minute temperature cycles consisting of 15 second baths of 60°C, 37°C, 5°C and 37°C respectively. Their rationale for using four water baths was that the maximum thermal gradient in enamel develops within one second after exposure, and the temperature rapidly returns to oral temperature once extreme environments are removed. Smith *et al.*[6] used 150 cycles of one minute baths in 8°C and 45°C water. Salzmann[56] noted that prolonged exposure to heat, moisture, and severe temperature changes significantly decreases the shear strength of the enamel-resin interface, but not of the ceramic-silane-acrylic bond. He also noted that stress is not severe enough to produce damage to the ceramic itself. In keeping with the protocol of previous bonding studies, specimens were stored in water at 37°C until debonding occurred, after which they were replaced into the water bath.[42,48,50,57] Bailey and Bennet[58] determined through long-term water storage tests that the cement bond with etch plus silane-treated ceramic surfaces demonstrated no significant decrease in strength after a one-year period under such storage conditions. Stacey[19] also used thermocycling in his study of the bond strength of ceramic veneers to enamel. He found that in all cases, materials subjected to this process have responded with significantly decreased bond strength. This was in contrast to the findings of Newburg and Pameijer[59], who concluded that thermal cycling did not affect bond strengths. Diaz-Arnold and Aquilino[54] evaluated the bond strengths of four organosilane materials in response to thermal stress. Thermocycling caused a significant decrease in the bond strengths of the Command® Ultrafine, Enamelite® 500, and Fusion®, but had no effect on Scotchprime®, which maintained consistently high shear strength values. A later study found that Scotchprime® tended to have the most consistently effective results, based on standard deviations.[5]

1.5.9 Debonding

Whitlock *et al.*[15] examined surfaces of ceramic restorations (bicuspid button samples) and bracket bases by SEM following debonding in order to determine the failure patterns and the presence of cracks and fractures. Ceramic surfaces and accompanying brackets had been previously examined by one examiner under a dissecting light microscope at x30 magnification. Samples representative of each group were examined by SEM, with the result that those with silane applied displayed multiple failure patterns. Combination failures involved bracket/resin, cohesive, and ceramic/adhesive sites. The group with the highest bond strength involved a no-mix cement and use of a priming agent. None of the samples displayed fractures or cracks within the ceramic restoration. Samples met the minimal shear bond strength required to withstand normal orthodontic forces (6-8 MPa).

Methods/Techniques

The potential for enamel fractures and cracks following debonding raises questions about the safety of procedures used to remove brackets. Reports have indicated that the most consistent and atraumatic debonding technique for metal brackets involves application of a force that peels the bracket base away from the tooth and causes bond failure at the adhesive-bracket interface.[39] It is important for clinicians to be aware that relatively strong forces are required to obtain bond failure, which may result in various degrees of patient discomfort. In the clinical setting, such a force would be transmitted to teeth that are often mobile and sometimes sensitive to pressure at the end of the active phase of orthodontic treatment. To reduce such trauma, teeth should be well supported during bracket removal.

The orthodontist should have the patient bite firmly into a cotton roll to help stabilize these sensitive and relatively mobile teeth.[60]

Sheridan *et al.*[61] noted that contemporary techniques of metal bracket removal require shearing or compression forces. Britton *et al.*[62] suggested that mechanical removal of ceramic brackets involves not only shearing forces, but also torsional forces. Metal bracket removal has generally been accomplished with mechanical crimping instruments. The force necessary to separate the bracket from the tooth is sufficient to cause deformation of the bracket and, occasionally, is capable of damaging the tooth. Oliver[63] compared three different methods of debonding metal edgewise orthodontic brackets: i) the mesial and distal wings were squeezed together with pliers; ii) a shear force was applied with a ligature cutter; iii) a tensile force was applied by a lift off debracketing instrument (LODI). The first two methods produced bracket distortion in 30% cases, while the LODI produced distortion only 3% of the time. Other investigations have determined that metal brackets will deform 20% under stress before fracturing, while ceramic brackets will deform less than 1% before failing.[39,64] Bishara and Fehr[65] compared the effectiveness of wide and narrow bladed pliers in debonding ceramic brackets. They concluded that narrow blades effectively debond ceramic brackets with a significantly lower mean debonding force than wider blades.

Andreasen and Stieg[9] issued the precaution that bond strength between resin and ceramic restorations with silane applied is sufficient to cause fracture of the ceramic. Smith *et al.*[6] found that damage occurred not only in conditions of roughened ceramic and silane, but also with glazed ceramic and silane. Therefore they proposed bracket removal from a ceramic surface occurs with a tensile pull involving "pinching and peeling" force. Site of failure will occur within the composite.

Zachrisson and Buyukyilmaz[13] noted that a gentle debonding technique is necessary to achieve failure at a metal bracket/adhesive interface and to avoid ceramic restoration fracture. They suggested a 45° outward peripheral force be applied to the gingival tie wings of twin brackets with an anterior bond-removing plier, or by squeezing the wings with a Weingart plier.

Carter[66] reported no instances of enamel fracture related to debonding approximately 2000 ceramic brackets over a three year period. He noted that the problem with bracket removal is not the enamel/adhesive bond, but inflexibility of the bracket itself. He suggested that ceramic bracket removal should be accomplished by using a shielded debonding instrument to grasp the bracket sides parallel to the long axis of the tooth, not occlusogingivally. He proposed that the tooth be supported lingually with a finger while rotating the bracket off with a twisting force.

Starling and Love[67] noted that torsional or shear forces have been recommended for ceramic brackets as opposed to peeling forces used for removal of metal brackets. They investigated the effectiveness of using plasticizers to modify mechanical properties of the adhesive to make bracket removal easier and more predictable. The addition of this plasticizer was found to lower the peak torque required for ceramic bracket removal, making cohesive fracture within the adhesive more likely. This would be of benefit in maintaining the integrity of the veneer surface, assuming that bond strength would still be clinically relevant.

Pus and Way[68] evaluated enamel damage resulting from debonding brackets with either filled or unfilled resin. Their protocol involved gently squeezing mesial and distal wings of metal brackets with Howe pliers while applying a slight twisting action, and then removing residual resin with either hand or rotary instruments. Hand instrumentation was associated with a mean loss of enamel of 7.7 μm while 17.2 μm occurred with rotary instrumentation.

The latest development in bracket removal techniques has been electrothermal debonding. Rueggeberg and Lockwood[69] have found that there is a direct relationship between filler content of the bonding resin and debonding temperature. In addition, there is an inverse exponential relationship between debonding temperature and load needed to cause debracketing. Their findings indicated that thermal debonding produced no evidence of overt enamel fracture, and failure site shifted toward the tooth/resin interface. The higher the resin temperature, the less debonding force is required and the less potential for enamel damage is present. Because operators and their force application capabilities differ, it is not possible to determine clinical forces delivered during thermal debracketing. A previous investigation has determined that at room-temperature testing (23°C), brackets require 347N (78 pounds) of force for debonding from enamel.[69] Raising the resin temperature to 75°C results in a halving of the applied force necessary (147N) to remove the bracket. This lower force would substantially decrease the chances of enamel damage during bracket removal. Also, this temperature of 75°C is a much lower risk to the dental pulp than the more elevated temperatures associated with ETD™. Anecdotal reports by Wool[70] indicated that by simply having a patient rinse with hot water prior to bracket removal, clinical debonding forces were noticeably reduced. Gorbäck[71] reported on a thermal bracket removal technique which involved heating the tips of a utility plier for about 10 seconds with a micro torch. Although the technique was clinically successful in bracket removal, safety of the pulp was not addressed. The debonding temperature associated with Rely-A-Bond at the tooth/resin interface has been confirmed as 154°C ± 13°C.[72] Sheridan *et al.*[61] found that temperatures involved with the ETD™ are safe to the pulp, and that when water spray was used immediately following bracket removal, the mean ultimate increase in pulpal wall temperature was less than 1°C.

Rueggeberg and Lockwood concluded that a wide variation exists in the temperature needed to thermally debond stainless steel brackets.[69] Two-paste systems required greater heat than did no-mix systems. Powder/liquid systems required the least heat. Debonding at room temperature tended to demonstrate failure sites at the bracket/resin interface except for cohesive enamel fractures. At elevated temperatures, site of failure shifted toward the tooth/resin interface. There was no evidence of overt enamel fracture when debonding was done at elevated temperatures. However, debonding occurred at higher temperatures when resins with greater filler contents had been used. Products with less than 54% filler tended to fail primarily at the bracket/resin interface when a load of 22.2 N was used. Materials with a higher filler content displayed failures at both the bracket/resin and tooth/resin surfaces. Ostertag *et al.*[43] concluded that no significant difference existed in the site of bond failure as the concentration of adhesive changed. Sheridan[61] proposed the hypothesis that deformation of resin material at the metal bracket base resulted in bond failure when the ETD™ instrument is used. It could similarly be suggested that the heat transferred to the ceramic bracket base and the composite resin results in the deformation of a layer of adhesive material closest to the bracket. Since the thermal expansion properties of the adhesive material differ from those of the aluminum oxide bracket material, the resulting difference in contraction and expansion at this interface, accompanied by slight torquing by the clinician, are sufficient to break the chemical bond between the polymers of the adhesive and the silane coupling agent of the bracket base.[60] Ideally, the debonding technique should result in adhesive failure at the ceramic/resin interface, leaving the original glazed surface. However, clinical experience has shown that bond failure usually occurs at the resin/bracket interface, leaving residual composite to be removed.[6]

Bishara and Trulove[39] evaluated several variables during and after ceramic bracket removal It was found that incidence of bracket failure was significantly greater with conventional debonding techniques versus ultrasonic or electrothermal methods. Cohesive resin failure occurred with mechanical debonding, while the site of failure for ETD was the bracket-resin interface. Debonding times were similar for conventional and ETD debonding techniques, but longer for ultrasonic debonding.

Forces

Bond strength of bonded brackets relies on a number of factors, specifically bracket type, adhesive, and enamel conditioner used.[46] An important consideration in bracket choice is underscored by Maskeroni *et al.*[57], who noted that the shear force needed to mechanically debond ceramic brackets is 21% greater than that required to debond metal brackets. Viazis *et al.*[73] noted that the fracture toughness for ceramics is 20 to 40 times less than those of stainless steel. Clinically, the bond strength of metal or ceramic brackets seems to be more than adequate. Bishara *et al.*[46] have estimated the debonding strength of ceramic brackets as equivalent to 5.88 MPa when using a sharp edged debonding instrument.

Kao and Johnston[14] found that a higher average debonding force was required to remove a bracket from a ceramic surface roughened with a green stone.

Scott[64] stated that tensile strength of metals is a bulk material property that can be a very appropriate indicator of performance in orthodontic applications with little or no regard for surface condition. Tensile strength of ceramics is not a simple bulk material property; it is dependent on the condition of the ceramic surface so tests on bulk samples of material can be irrelevant and misleading. The ability of a material to resist fracture (breakage) is the mechanical property that most distinguishes ceramics from metals. This ability is called fracture toughness. Tensile strength of sapphire brackets is 1379 MPa while that of stainless steel is only 345 MPa. However, the elongation (strain -- the amount of deformation per cm) for stainless steel is approximately 20% when it finally fails. The elongation for the sapphire at failure is less than 1%.[39,64]

Enamel Fractures

Fox and McCabe[74] noted that the bond strength of orthodontic ceramic brackets is higher than metal brackets and many incidents of enamel fracture have been reported. A report by the American Association of Orthodontists indicated that 21% of orthodontists had seen damage to enamel due to ceramic brackets.[75]

The vast majority of bonding/debonding studies have involved enamel surfaces. Much has been documented regarding sites of failure and enamel damage. The sites of failure are interesting to note and compare to debonding from ceramic surfaces in an attempt to better understand the exact mechanisms involved.

Bishara *et al.*[46] reported Retief's finding that enamel fractures may occur with bond strength as low as 13.54 MPa. Due to their rigidity, ceramic brackets require a higher force to debond, so the preferable site of failure would be either resin/bracket or enamel/resin interface. It would seem logical to reduce the bond at the enamel/resin interface to reduce risk of enamel fracture, enhance debonding and cleanup, and decrease damage done to enamel.

Hill[76] found that even when manufacturers' recommended methods of debonding were used, enamel damage was produced in 34% of teeth bonded with silanated single crystalline brackets and in 13% of silanated polycrystalline brackets. Ghafari *et al.*[77] and Eliades *et al.*[78] found rates of enamel fracture associated with silanated polycrystalline brackets to be 5.5% and 5%, respectively.

Ceramic Veneer Fractures

Zachrisson and Buyukyilmaz[13] noted that despite the thin and fragile nature of ceramic veneers, luting resins appear to provide increased resistance to fracture. The bond between the laminate and the tooth is stronger than that between the laminate and a bracket. Kao and Johnston[14] found no incidence of total fracture or dislodging of the veneer, and an 11% incidence of microfracture in a sample of 160 brackets bonded to Ceramco® (Ceramco Inc., Burlington, N.J.) ceramic laminate veneers. Samples fabricated from Vita® ceramic, however, had surface crazing or other cohesive failure at a rate of 25%. Smith *et al.*[6] found that debonding failure occurred within the ceramic in all specimens with glazed or roughened surfaces treated with silane. When ceramic brackets were cemented to etched ceramic veneers, Simonsen and Calamia[79] found veneer fractures occurred in all cases.

Messer *et al.*[80] noted that for a flaw to initiate fracture it must have a sharp crack-like feature associated with it. Flaws can occur on the edges, surfaces and in the volume of a ceramic, and for the same size, their severity decreases in that order. In strong ceramics, surface and edge flaws, which may be formed during surface grinding or from abrasion in service, might grow by stress corrosion to initiate fracture. Flaws in ceramics of low and modest strength are correspondingly larger, often appearing as pores. Pores can result from the burn-out of organic impurities or from non-uniform shrinkage.

Site of Failure

Reynolds[41] estimated the minimum tensile bond strength required by bonded attachments as being 5.88-7.84 MPa. Failure to withstand tensile or shearing forces is dependent on the strength of the bond between the enamel, adhesive, and attachment and on the surface area of the attachment. Kao *et al.*[8] found that the use of a silane primer increased the average debond force required for the resin and the ceramic veneer laminate. Although silane primer enhances the resin-ceramic bond, there is a higher incidence of ceramic fracture resulting from the increased debond forces exerted. They observed that 8.8% of their sample had ceramic fractures, with no incidence of total fracture or dislodging of the veneer. The bond between the laminate and tooth has been shown to surpass that between the bracket and laminate.

Zelos *et al.*[11] evaluated the bond strength of ceramic orthodontic brackets bonded to Vita and Ceramco dental ceramics, fashioned to duplicate the labial surface of maxillary right central incisors. Testing on an Instron Universal testing machine determined a mean shear bond strength of 10.70 kg and tensile bond strength of 3.92 kg. Failure was observed via stereomicroscope to have been at one of six locations: within the bracket, bracket-adhesive interface, cohesive resin, ceramic-adhesive interface, ceramic fracture, and ceramic cracking. They found that shear forces produced a ceramic crack/fracture in 42% of cases. Tensile forces were associated with no such veneer damage, but failure often occurred at the bracket/adhesive junction (61.4%) and the ceramic/adhesive junction (10.8%). Clinical debonding techniques which utilize cutters or pliers produce a tensile/peeling effect. Zelos *et al.*[11] concluded that bond strengths obtained between ceramic brackets and glazed ceramic are not only clinically sufficient to withstand orthodontic forces, but are comparable to the bond strengths between ceramic brackets and enamel.

Nathanson[16a] described the existence of different failure mechanisms, depending on the pre-treatment of ceramic veneers. Non-etched ceramic produced an adhesive failure between the resin and ceramic, and a flat resin surface remained unaffected. In etched ceramic groups, adhesive failures occurred within the ceramic structure. Lacy *et al.*[81] found that ceramic etched with hydrofluoric acid and treated with silane produced a comparable bond strength with etched enamel. It was noted that silane and acid-etched ceramic may produce bonds stronger than the cohesive strength of ceramic. Stangel *et al.*[27] compared the effectiveness of 52% and 20% hydrofluoric acid in etching ceramic surfaces. Their finding was that the 52% concentration preferentially dissolved the glassy phase while the 20% concentration preferentially dissolved the crystalline phase. All etching methods resulted in increased bond strength. Nicholls[12] found that ceramic veneer bond strength increased proportional to etch time with 7.5% hydrofluoric acid and with use of a silane coupling agent.

They also noted that a clinically acceptable tensile bond strength between the ceramic veneer and the cementing resin is 27.58 MPa. Calamia *et al.*[30] had previously demonstrated with a 5% hydrofluoric acid concentration that bond strengths were significantly greater for 2.5 minute versus 20 minute etch times.

Viazis *et al.*[24] determined that the failure of mechanical bonds (metal foil mesh and grooved-based ceramic bracket bases) under shear stress is primarily within the adhesive itself (brittle failure of the adhesive from localized stress areas), whereas chemical bonds (silane-treated ceramic bracket bases) fail mostly at the adhesive-bracket interface (pure failure caused by wider stress distribution over the whole interface). This confirmed the previous finding of Dickinson and Powers[82] that bond failures occurred most frequently at the base-adhesive interface of the metal bases. Joseph and Rossouw[42] found that the failure sites with metal brackets are evenly divided between the bracket/resin and the resin/enamel interfaces. However, in a separate study they demonstrated that metal brackets bonded with fissure sealant fail primarily at the resin/enamel interface.[83] Gwinnett[84] concluded that both metal and ceramic brackets failed consistently at the resin/bracket base interface. For ceramic brackets debonded from ceramic surfaces, Zelos *et al.*[11] determined that the site of failure depended to some extent on the type of force being produced. Shear forces created ceramic fractures, while tensile forces resulted in significant failures at the bracket/adhesive junction and less often at the ceramic/adhesive junction.

The highest incidence of ceramic fractures associated with debonding occurred in roughened, silane primed surfaces bonded with highly filled resin. Highly filled resins require a higher force to debond brackets on either natural teeth or ceramic veneer laminates.

Roughening (including etching) a ceramic surface further increases resistance to debond forces, probably by addition of mechanical retention.[5,6,27] Smith *et al.*[6] suggested that these bond strengths are certainly within the realm of achieving clinical success. Eustaquio *et al.*[10] found no significant difference between bond strengths of glazed and deglazed ceramics. Stangel *et al.*[27] confirmed that silane increased the bond strength of composite resin to etched ceramic. Zelos *et al.*[11] also reported the ceramic glaze strengthens the ceramic and reduces crack propagation.

Whitlock *et al.*[15] found that when no ceramic primer was used to adhere ceramic brackets to ceramic restorations, the bond failed at the restoration-adhesive interface. In each case, the adhesive remained attached to the bracket and not to the restoration surface. Samples in groups that had received a priming agent displayed multiple failure patterns. There was a combination of failure at the bracket-adhesive interface, within the adhesive, and at the restoration-adhesive interface. None of the samples displayed fractures or cracks within the veneers or the ceramic brackets.

Evans and Powers[52] noted sites of failure as being within cement, at the cement-base interface, or at the cement-substrate interface. The failure site observed for no-mix cements was essentially at the cement-base interface. Failures within the cement were characterized by incomplete polymerization of the resin. Cement consistency is an important factor in determining the critical cement thickness at which failure begins within the cement. As cement consistency increases, there is less mixing of the primer and paste and less diffusion of the free radicals from the primer/paste interface. Thus, less polymerization occurs, leading to a decrease in tensile bond strength. Odegaard and Segner[49] demonstrated that light cured adhesives have similar bond failures as chemical cured resins. Eversoll and Moore[45] noted that unfilled resins resulted in site of failure being at the enamel/adhesive junction. Addition of inorganic fillers increases the cohesive strength of the bonding adhesive layer. This has resulted in failure occurring at the bracket/resin interface for metal, plastic, and ceramic brackets.[45,47]

In late 1986, the first brackets made of ceramic material became widely available. Subsequently, anecdotal reports of bracket breakage and tooth damage associated with the use of ceramic brackets have been published. Ideally, fracture sites associated with bracket debonding should be consistently at the resin/enamel interface with no enamel damage. Since enamel damage does occur, a fracture site at the interface between resin and bracket is clinically acceptable. Joseph and Rossouw[83] demonstrated mainly resin/enamel fracture sites when a primary coating of fissure sealant was applied to the enamel surface before stainless steel brackets were bonded. Carter[66] reported excessive bond strengths leading to bracket and/or enamel fracture when sapphire brackets with both mechanical retention grooves and a silane coupler were used. Storm[85] describes a chemical bond between resin and bracket base that is a stronger bond than between resin and enamel, when silane is used.

Rueggeberg and Lockwood[72] felt that crystal sapphire brackets, because of their optical clarity, provide an esthetic advantage over many other types of brackets. Debonding of these brackets has caused iatrogenic damage to enamel. Thermal debonding has been proposed for use in removing sapphire brackets without causing damage to teeth. Two-paste products have been found to have a markedly higher debonding temperature than the no-mix materials when debonding stainless steel brackets. It is important to know the relative thermal debonding temperature of a particular orthodontic bonding resin prior to placing brackets. The lower the debonding temperature, the less the potential for pulpal damage during debonding.

Pulpal Response to Electrothermal Debonding

The electrothermal debonding process involves heating the bracket surface until the underlying resin no longer adheres, allowing the bracket removal.[69] The electrothermal debracketing instrument transfers heat through the bracket, allowing bond failure at the bracket-adhesive interface as the heat denatures the adhesive.[39] Heat transfer through solid substances occurs by a process known as conduction. The coefficient of thermal conductivity is expressed as the quantity of heat in calories per second that passes through a specimen 1 cm thick having a cross-sectional area of 1 mm^2 when the temperature differential between the ends of the specimen is 1°C.[28] The higher the coefficient of thermal conductivity, the greater is the ability of the substance to transmit heat and vice versa. Enamel and dentin are effective thermal insulators, with thermal conductivity values of 0.0022 cal.cm/cm^2.sec.°C and 0.0015 cal.cm/cm^2.sec.°C respectively. Ceramic compares favourably at 0.0025 cal.cm/cm^2.sec.°C Specific heat of a material is the heat capacity per specific mass of material. Values for enamel, dentin, and ceramic are 0.18 cal/gm/°C, 0.28 cal/gm/°C, and 0.26 cal/gm/°C respectively (as compared to the standard of water at 1.0 cal/gm/°C).[28] Removal of a layer of enamel which is replaced with a layer of ceramic of equal thickness should, therefore, not affect the conduction of heat from the ETD™ tip through to the dental pulp. Little data have been reported regarding intrapulpal temperature changes in response to electrothermal debracketing.

Investigation has shown that ETD does not raise the pulpal wall temperature to a level that has the potential for causing histologic damage.[86] Vukovich *et al.*[87] found that temperatures exceeding the known thresholds for pulpal damage are generated when ceramic brackets were ground off by low-speed without coolant. However, when a similar procedure was performed using high speed and water or air coolant, temperatures were significantly lower than threshold values.

Robinson and Lefkowitz[88] have stated that, "Excessive heat is the most serious single insult to the pulp . . . All possible injuries, one added to the other, must be avoided". Zach and Cohen[89] have shown that it is both the quantity and intensity of heat applied to the pulp which may be important.

The literature describes methods used to measure the degree of heat transferred from the tooth surface to pulp chamber during electrothermal debonding. All have used a thermocouple placed on the buccal wall within the pulp chamber of the tooth. However, the pulpal chamber has been infused with various materials to assist in the conduction or dissipation of external heat. Grajower *et al.*[90] simulated the blood circulation by injecting 37°C water into the pulp chamber with a syringe pump during the debonding procedure. Sheridan *et al.*[61], and Heithersay and Brannstrom[91] placed a silicone oil medium around the thermocouple tip for heat-conduction efficiency. Ulusoy *et al.*[92] filled the pulp chamber with dry aluminum powder, while Vukovich *et al.*[87] simulated in vivo conditions by using a pulp tissue replacement, type Z9 heat sink compound.

Jost-Brinkmann *et al.*[93] studied the effect of thermal debonding on the pulp tissue of teeth bonded with either metal or ceramic brackets. Their review of thermal effect experiments noted a temperature of 40°C produces circulation changes in the pulp tissue, and thrombosis if maintained at that level. A temperature rise to 46°C lasting for two minutes leads to a complete arrest of the blood circulation. Zach and Cohen[89] have demonstrated that a thermal stress of 275°C for only a few seconds has the potential to produce irreversible pulp damage.

Sheridan *et al.*[61] reported that pulpal pathosis is directly proportional to the increase in temperature. They determined that temperature increases produced by the ETD of metal brackets were not sufficient to cause pulpal damage. Their results showed that the ETD produced a temperature increase at the pulp wall of 0.8°C. This was well below the threshold temperature of 5.5°C for primates, established by Zach and Cohen.[89] Lack of heat exchange between the ETD™ unit and the pulpal wall was attributed to dentin having a low thermal conductivity and insulating effect, and tissue fluid in the dentinal tubules may dissipate some heat. The time required for the ETD™ to remove a bracket was not correlated with pulpal temperature. This may have been due to differences in bond quality, varying degrees of traction applied to the bracket during the process, ETD™ tip seating differences, and differences in the level of battery charge. They did find that the temperature of the metal bracket at the time of lift-off was 130°C (± 15°C) with a mean debonding time with the ETD™ was 8 seconds. The ultimate pulp temperature increase was 0.12°C and 2.4°C, when the water coolant was used or not used respectively.

In a second study, Sheridan *et al.*[86] investigated the histologic response of human bicuspids to electrothermal debonding of metal brackets. Teeth were extracted two weeks following the debonding procedure and prepared for histologic examination, finding no evidence of pulpal pathosis related to ETD™.

Zach and Cohen[89] found that an intrapulpal temperature rise of 11.1°C results in a 60% rate of pulpal pathosis. A 5.5°C increase produced pulp death 15% of the time, while temperature increases under 5.5°C generally displayed pulp recovery. Cohen and Chase[94] investigated the pulpal response to vital bleaching, involving temperatures of 46°C to 57.1°C. Results indicated 73% of patients felt pain for up to 24 hours, but that none of the teeth became non-vital after 30 days.

During thermal debonding, it is important that the bracket comes off with the first heating cycle so the heat capacity is removed from the tooth before radiating to the pulp. It is advantageous to raise the heating temperature or to prolong the heating period until debonding occurs instead of running several heating cycles with the bracket remaining on the tooth.

While Sheridan[86] states 130°C as the temperature of resin when debonding occurs, Gerkhardt *et al.*[90] estimate approximately 100°C. A previous investigation of several bonding adhesives revealed that each resin material softens at a different temperature. Sheridan reported that thermodebonding of metal brackets was effective and produced no obvious pulp damage. None of the teeth with metal brackets showed any pathologic alterations after debonding. In all cases more than two-thirds of the adhesive resin remained on the tooth and no enamel fractures were found.

Brouns *et al.*[95] recorded the pulpal wall temperature increase during electrothermal debonding with two different instrument models (De-bond 200®, Scheu-Dental Co., Germany;

Ceramic Bracket Debonding Unit®, Dentaurum® Co., Germany). Fracture site location was significantly different in the two ceramic bracket types tested after electrothermal debonding. Their protocol involved pressing the bracket firmly into place with finger pressure on the buccal surface of each premolar and immediately removing excess paste. Before electrothermally debonding the brackets, the teeth were stored at 37°C in distilled water for at least 24 hours to ensure complete polymerization of all the resin material. The pulp chamber was filled with 0.9% sodium chloride for heat-conduction efficiency. Under normal circumstances, the average pulp temperature rise for electrothermal debonding Transcend® and Fascination® brackets with the De-bond 200® device was 1.1°C. For the Ceramic Bracket Debonding Unit®, the average temperature rise varied between 3.6° and 5.2°C. They found that the average temperature rise for debonding ceramic brackets varies between 1.8° and 2.0°C. Ceramic Bracket Debonding Unit® with Fascination® brackets found an average temperature increase between 3.0° and 5.0°C. Bishara and Trulove[60] found that after electrothermal debonding Starfire® brackets, 85% of the bond failures were located in the bracket-adhesive interface. Brouns *et al*[95]. determined that temperatures at both bracket bases varied between 208°C and 230°C without air cooling and dropped to 74°-126°C when subsequent air cooling was used.

1.5.10 Evaluation of Ceramic Surfaces

Adhesive Remnant Index

Evaluation of residual adhesive and site of bond failure should follow a specific method. Bishara and Trulove[39] assessed adhesive remaining after bracket removal, according to the Adhesive Remnant Index (ARI) with respect to the amount of resin material adhering to the enamel surface. The scale used had a range between 5 and 1, with 5 indicating that no composite remained on the enamel; 4, less than 10% of composite remained on the tooth surface; 3, more than 10% but less than 90% of the composite remained on the tooth; 2, more than 90% of the composite remained; and 1, all of the composite remained on the tooth, along with the impression of the bracket base. The ARI was also used as a more complex means of defining the site of bond failures between the enamel, adhesive, and bracket base. The ARI has also been used by Bishara and Fehr[65] to determine the site of bond failure.

Zachrisson *et al.*[96] conducted a comparative study on different methods of detecting enamel cracks. They evaluated direct illumination, indirect illumination (reflected from the lingual), shadowing via direct or indirect illumination, staining with a penetrant dye (methylene blue), and transillumination with fiber-optic light. They concluded that fiber-optic transillumination and shadowing with direct illumination were clearly superior. The majority of cracks were oriented parallel to the long axis of teeth, and were classified as pronounced (detectable under normal office illumination) or weak (requiring extra illumination for detection). Only 25-30% of teeth were without cracks in the Zachrisson study. Redd and Shivapuja[75] utilized methylene blue to identify fractures which existed prior to orthodontic bonding and debonding. Follow-up with SEM confirmed that teeth with cracks revealed by staining showed enamel damage in the corresponding areas, while those that did not accept a stain showed no microscopic damage.

BIBLIOGRAPHY

1. Lee-Knight CT, Bell RD, Faulkner RA, Schneider VE: Protective Mouthguards and Sports Injuries. Canadian Dental Association Journal. 1991;57:39-41

2. Bell RD, Faulkner RA, Lee-Knight CT, Schneider VE, Towriss BD: Bimaxillary and Standard Mouthguards and Their Effect on Football Performance. The Canadian Athletic Therapists Association Journal. 1991 Issue.

3. Proffit WR, Fields HW: Contemporary Orthodontics 2nd Ed. Mosby Year Book, Inc. St. Louis.

4. Alexander RG: The Alexander Discipline. Edited by Gary A. Engel. Published by Ormco® Corporation 1986

5. Major PW, Koehler JR, Manning KE: 24 Hour Shear Bond Strength of Metal Orthodontic Brackets Bonded to Porcelain Using Various Adhesion Promoters. Am.J.Orthod.Dentofac.Orthop. (1995 in press)

6. Smith GA, McInnes-Ledoux P, Ledoux WR, Weinberg R: Orthodontic bonding to porcelain -- bond strength and refinishing. Am.J.Orthod.Dentofac.Orthop. 1988;94:245-252

7. Wood DP, Jordan RE, Way DC, Galil K: Bonding to porcelain and gold. Am.J.Orthod. 1986; 89:194-205

8. Kao EC, Boltz KC, Johnston WM Direct bonding of orthodontic brackets to porcelain veneer laminates. Am.J.Orthod.Dentofac.Orthop. 1988;94:458-68

9. Andreasen GF, Stieg MA: Bonding and debonding brackets to porcelain and gold. Am.J.Orthod.Dentofac.Orthop. 1988;93:341-5

10. Eustaquio R, Garner LD, Moore BK: Comparative tensile strengths of brackets bonded to porcelain with orthodontic adhesive and porcelain repair systems. Am.J.Orthod.Dentofac.Orthop. 1988;94:421-5

11. Zelos L, Bevis RR, Keenan KM: Evaluation of the ceramic/ceramic interface. Am.J.Orthod.Dentofac.Orthop. 1994;106:10-21

12. Nicholls JI: Tensile bond of resin cements to porcelain veneers. J.Prosthet.Dent. 1988; 60:443-7

13. Zachrisson BU, Buyukyilmaz T: Recent Advances in Bonding to Gold, Amalgam, and Porcelain. J.Clin.Orthod. 1993;27:661-75

14. Kao EC, Johnston WM: Fracture incidence on debonding of orthodontic brackets from porcelain veneer laminates. J.Prosth.Dent. 1991;66:631-7

15. Whitlock BO, Eick JD, Ackerman RJ, Glaros AG, Chappell RP: Shear strength of ceramic brackets bonded to porcelain. Am.J.Orthod.Dentofac.Orthop. 1994;106:358-64

16. Garber DA, Goldstein RE, Feinman RA: Porcelain Laminate Veneers Quintessence Publishing Co., Inc. 1988
16a) Nathanson D: in Porcelain Laminate Veneers Quintessence Publishing Co., Inc. 1988

17. Wall JG, Cipra DL: Alternative Crown Systems: Is the Metal-Ceramic Crown always the Restoration of Choice? Dental Clinics of North America. 1992;36:765-782

18. Sheets CG, Taniguchi T: Advantages and limitations in the use of porcelain veneer restorations. J.Prosthet.Dent. 1990;64:406-11

19. Stacey GD: A shear stress analysis of the bonding of porcelain veneers to enamel. J.Prosthet.Dent. 1993;70:395-402

20. Andreasen FM, Flugge E, Daugaard-Jensen J, Munksgaard EC: Treatment of crown fractured incisors with laminate veneer restorations. An experimental study. Endod.Dent.Traumatol. 1992;8:30-35

21. Sheets CG, Taniguchi T: A multidie technique for the fabrication of porcelain laminate veneers. J.Prosthet.Dent. 1993;70:291-5

22. Sorensen JA, Strutz JM, Avera SP, Materdomini D: Marginal fidelity and microleakage of porcelain veneers made by two techniques. J.Prosthet.Dent. 1992;67:16-22

23. Karlsson S, Landahl I, Stegersjo G, Milleding P: A Clinical Evaluation of Ceramic Laminate Veneers. Int.J.Prosthodont. 1992;5:447-51

24. Viazis AD, Cavanaugh G, Bevis RR: Bond strength of ceramic brackets under shear stress. Am.J.Orthod.Dentofac.Orthop. 1990;98:214-21

25. Tay WM, Lynch E, Auger D: Effects of some finishing techniques on cervical margins of porcelain laminates. Quintessence International 1987;18:599-602

26. Buonocore MG: A Simple Method of Increasing the Adhesion of Acrylic Filling Materials to Enamel Surfaces. J.D.Res. 1955;34:849-53

27. Stangel I, Nathanson D, Hsu CS: Shear Strength of the Composite Bond to Etched Porcelain. J.Dent.Res. 1987;66:1460-5

28. Phillips RW: Science of Dental Materials. W.B. Saunders Company, Philadelphia 1991

29. Newman GV: Bonding to Porcelain. J.Clin.Orthod. 1983;17:53-5

30. Calamia Jr, Vaidyanathan J, Vaidyanathan TK, Hirsch SM: Shear Bond Strength of Etched Porcelains. IADR/AADR Abstracts 1985. J.Dent.Res. 1985;64:1091

31. Eliades T, Lekka M, Eliades G, Brantley WA: Surface characterization of ceramic brackets: A multitechnique approach. Am.J.Orthod.Dentofac.Orthop. 1994;105:10-18

32. Birnie D: Ceramic Brackets. British Journal of Orthodontics. 1990;17:71-5

33. Horn HR: Porcelain laminate veneers bonded to etched enamel. Dent.Clin.North Am. 1983;27:671

34. Hsu CS, Stangel I, Nathanson D: Shear Bond Strength of Resin to Etched Porcelain. IADR/AADR Abstracts 1985. J.Dent.Res. 1985;64:1095

35. Ghassemi-Tary B: Direct bonding to porcelain: An in vitro study. Am.J.Orthod. 1979;76:80-3

36. Suliman AHA, Swift EJ, Perdigao J: Effects of surface treatment and bonding agents on bond strength of composite resin to porcelain. J.Prosthet.Dent. 1993;70:118-20

37. Highton RM, Caputo AA, Matyas J: Effectiveness of porcelain repair systems. J.Prosthet.Dent. 1979;42:157-61

38. Nebbe B, Stein E: Orthodontic Brackets Bonded to Glazed and Deglazed Porcelain Surfaces. Unpublished manuscript. Department of Orthodontics, University of the Witwatersrand, Johannesburg

39. Bishara SE, Trulove TS: Different debonding techniques for ceramic brackets. Comparisons of different debonding techniques for ceramic brackets: An in vitro study
Part I. Background and methods. Am.J.Orthod.Dentofac.Orthop. 1990;98:145-53

40. Eliades T, Viazis AD, Eliades G: Bonding of ceramic brackets to enamel: Morphologic and structural considerations. Am.J.Orthod.Dentofac.Orthop. 1991;99:369-75

41. Reynolds IR: A Review of Direct Orthodontic Bonding. Br.J.Orthod. 1975;2:171-8

42. Joseph VP, Rossouw E: The shear bond strengths of stainless steel and ceramic brackets used with chemically and light-activated composite resins. Am.J.Orthod.Dentofac.Orthop. 1990;97:121-5

43. Ostertag AJ, Dhuru V, Ferguson D, Meyer R: Shear, torsional, and tensile bond strengths of ceramic brackets using three adhesive filler concentrations. Am.J.Orthod.Dentofac.Orthop. 1991;100:251-8

44. Rueggeberg FA, Maher FT, Kelly MT: Thermal properties of a methyl methacrylate-based orthodontic bonding adhesive. Am.J.Orthod.Dentofac.Orthop. 1992;101:342-9

45. Eversoll DK, Moore R: Bonding orthodontic acrylic resin to enamel. Am.J.Orthod. 1988;93:477-85

46. Bishara SE, Fehr DE, Jakobsen JR: A comparative study of the debonding strengths of different ceramic brackets, enamel conditioners, and adhesives. Am.J.Orthod.Dentofac.Orthop. 1993;104:170-9

47. Buzzitta VAJ, Halgren SE, Powers JM: Bond strength of orthodontic direct-bonding cement-bracket systems as studied in vitro. Am.J.Orthod. 1982;81:87-92

48. Klockowski R, Davis EL, Joynt RB, Wieczkowski G, MacDonald A: Bond strength and durability of glass ionomer cements used as bonding agents in the placement of orthodontic brackets. Am.J.Orthod.Dentofac.Orthop. 1989;96:60-4

49. Odegaard J, Segner D: The use of visible light-curing composites in bonding ceramic brackets. The use of visible light-curing composites in bonding ceramic brackets. Am.J.Orthod.Dentofac.Orthop. 1990;97:188-93

50. Knoll M, Gwinnett AJ, Wolff MS: Shear strength of brackets bonded to anterior and posterior teeth. Am.J.Orthod.Dentofac.Orthop. 1986;89:476-9

51. Coreil MN, McInnes-Ledoux P, Ledoux WR, Weinberg R: Shear bond strength of four orthodontic bonding systems. Am.J.Orthod.Dentofac.Orthop. 1990; 97:126-9

52. Evans LB, Powers JM: Factors affecting in vitro bond strength of no-mix orthodontic cements. Am.J.Orthod. 1985;87:508-12

53. Newman SM, Dressler KB, Grenadier MR: Direct bonding of orthodontic brackets to esthetic restorative materials using a silane. Am.J.Orthod. 1984;86:503-6

54. Diaz-Arnold AM, Aquilino SA: An evaluation of the bond strengths of four organosilane materials in response to thermal stress. J.Prosthet.Dent. 1989;62:257-60

55. Peterson EA, Phillips RW, Swartz ML: A comparison of the physical properties of four restorative resins. JADA 1966;73:1324-6

56. Salzmann JA: A New Method for direct bonding Orthodontic Attachments to Porcelain Teeth Using a Silane Coupling Agent: An In Vitro Evaluation [Review]. Am.J.Orthod. 1980;78:233-4.

57. Maskeroni AJ, Meyers CE, Lorton L: Ceramic bracket bonding: A comparison of bond strength with polyacrylic acid and phosphoric acid enamel conditioning. Am.J.Orthod.Dentofac.Orthop. 1990;97:168-75

58. Bailey L, Bennett R: DICOR Surface Treatments for Enhanced Bonding. J.Dent.Res. 1988;167:925-31

59. Newburg R, Pameijer CH: Composite resins bonded to porcelain with silane solution. J.Am.Dent.Assoc. 1978;96:288-91

60. Bishara SE, Trulove, TS: Comparisons of different debonding techniques for ceramic brackets: An in vitro study. Part II. Findings and clinical implications. Am.J.Orthod.Dentofac.Orthop. 1990;98:263-73

61. Sheridan JJ, Brawley G, Hastings J: Electrothermal debracketing Part I. An in vitro study. Am.J.Orthod. 1986;61:21-7

62. Britton JC, McInnes P, Weinberg R, Ledoux WR, Retief DH: Shear bond strength of ceramic orthodontic brackets to enamel. Am.J.Orthod.Dentofac.Orthop. 1990;98:348-53

63. Oliver RG: Distortion of edgewise orthodontic brackets associated with different methods of debonding. Am.J.Orthod.Dentofac.Orthop. 1989;96:65-71

64. Scott GE: Fracture Toughness and Surface Cracks -- The Key to Understanding Ceramic Brackets. The Angle Orthodontist. January 1988:5-8

65. Bishara SE, Fehr DE: Comparisons of the effectiveness of pliers with narrow and wide blades in debonding ceramic brackets. Am.J.Orthod.Dentofac.Orthop. 1993;103:253-7

66. Carter RN: Clinical Management of Ceramic Brackets. J.Clin.Orthod. 1989;23:807-9

67. Starling KE, Love BJ: Plasticization of Adhesive to Improve Debonding of Ceramic Brackets. J.Clin.Orthod. 1993;27:319-22

68. Pus MD, Way DC: Enamel loss due to orthodontic bonding with filled and unfilled resins using various clean-up techniques. Am.J.Orthod. 1980;77:269-83

69. Rueggeberg FA, Lockwood P: Thermal debracketing of orthodontic resins. Am.J.Orthod.Dentofac.Orthop. 1990;98:46-65

70. (25) Wool AL: A better debonding procedure. Am.J.Orthod.Dentofac.Orthop. 1992;Jul:84-86

71. Gorback NR: Heat Removal of Ceramic Brackets. J.Clin.Orthod. 1991;25

72. Rueggeberg FA, Lockwood PE: Thermal debracketing of single crystal sapphire brackets. The Angle Orthodontist. 1992;62:45-50

73. Viazis AD, Chabot K, Kucheria C: Scanning electron microscope (SEM) evaluation of clinical failures of single crystal ceramic brackets. Am.J.Orthod.Dentofac.Orthop. 1993;103:537-44

74. Fox NA, McCabe JF: An Easily Removable Ceramic Bracket? Br J.Ortho. 1992;19:305-9

75. Redd TB, Shivapuja PK: Debonding Ceramic brackets: Effects on Enamel. J.Clin.Orthod. 1991;25:475-81

76. Hill CB: A comparative study of three ceramic bracket systems and subsequent enamel damage upon debonding. Am.J.Orthod.Dentofac.Orthop. 1991;100:487

77. Ghafari J, Skanchy TL, Mante F: Shear Bond Strengths of Two Ceramic Brackets. J.Clin.Orthod. 1992;26:599-602

78. Eliades T, Viazis AD, Lekka M: Failure mode analysis of ceramic brackets bonded to enamel. Am.J.Orthod.Dentofac.Orthop. 1993;104:21-6

79. Simonsen RJ, Calamia J: Tensile bond strength of etched porcelain. J.Dent.Res. 1983;62:297.

80. Messer P, Piddock V, Lloyd C: The strength of dental ceramics. J.Dent. 1991;19:51-5

81. Lacy AM, LaLuz J, Watanabe LG, Dellinges M: Effect of porcelain surface treatment on the bond to composite. J.Prosthet.Dent. 1988;60:288-91

82. Dickinson PT, Powers JM: Evaluation of fourteen direct-bonding orthodontic bases. Am.J.Orthod. 1980;78:630-9

83. Joseph VP, Rossouw PE: The shear bond strengths of stainless steel orthodontic brackets bonded to teeth with orthodontic composite resin and various fissure sealants. Am.J.Orthod.Dentofac.Orthop. 1990;98:66-71

84. Gwinnett AJ: A comparison of shear bond strengths of metal and ceramic brackets. Am.J.Orthod.Dentofac.Orthop. 1988;93:346-8

85. Storm ER: Debonding ceramic brackets. J.Clin.Orthod. 1990;23:91-4

86. Sheridan JJ, Brawley G, Hastings J: Electrothermal debracketing Part II. An in vivo study. Am.J.Orthod. 1986;89:141-5

87. Vukovich ME, Wood DP, Daley TD: Heat generated by grinding during removal of ceramic brackets. Am.J.Orthod.Dentofac.Orthop. 1991;99:505-12

88. Robinson HDG, Lefkowitz W: Operative dentistry and the pulp. J.Prosthet.Dent. Vol.12, 1962

89. Zach L, Cohen G: Pulp response to externally applied heat. Oral.Surg.Oral.Med.Oral.Pathol. 1965;19:515-30

90. Grajower R, Shaharbani S, Kaufman E: Temperature rise in pulp chamber during fabrication of temporary self-curing resin crowns. J.Prosthet.Dent. 1979;41:535-40

91. Heithersay GS, Brannstrom M: Observations on Heat-Transmission Experiments with Dentin. 1. Laboratory Study. J.Dent.Res. 1963;42:1140-5

92. Ulusoy N, Denli N, Atakul F, Nayyar A: Thermal response to multiple use of a twist drill. J.Prosthet.Dent. 1992;67:450-3

93. Jost-Brinkmann PG, Stein H, Miethke RR, Nakata M. Histologic investigation of the human pulp after thermodebonding of metal and ceramic brackets. Am.J.Orthod.Dentofac.Orthop. 1992;102:410-17

94. Cohen SC, Chase C: Human pulpal response to bleaching procedures on vital teeth. J.Endod. Vol.5, 1979

95. Brouns EM, Schopf PM, Kocjancic B: Electrothermal debonding of ceramic brackets. An in vitro study. European Journal of Orthodontics. 1993;15:115-23

96. Zachrisson BU, Skogan O, Hoymyhr S: Enamel cracks in debonded, debanded, and orthodontically untreated teeth. Am.J.Orthod. 1980;77:307-19

Chapter Two

Research Paper

Mechanical and Electrothermal Debonding: Effect on Ceramic Veneers and the Dental Pulp

2.1 Introduction

Patients with excessive overjet have a significantly greater risk of fractured teeth, requiring placement of permanent restorations.[1,2,3,4] Restorative procedures include ceramic veneers which cover the entire labial surface and replacing missing tooth structure. Subsequent orthodontic treatment requires materials which are able to effectively bond brackets to ceramic surfaces.

An important advancement in bonding materials has been the development of organosilanes. Using organosilanes as surface primers, clinically acceptable bond strengths can be achieved without mechanical preparation of the ceramic. Elimination of mechanical preparation of the surface reduces risk of microcrack formation within ceramic veneers. Instead, Zachrisson[5] has suggested that surface alterations using micro-etchers provide improved bonding without adversely affecting the ceramic strength.

Previous studies have examined bond strength and debonding techniques involving orthodontic brackets and ceramic fused to metal crowns, but few have studied the effect on ceramic veneers.[6,7] Minimal veneer thickness (0.3 to 0.5 mm) may predispose this restoration to more frequent damage than full coverage crowns. Achieving satisfactory bond strengths for orthodontic treatment may result in ceramic fracture with debonding.[8] Previous investigations have demonstrated effective electrothermal debonding of metal brackets from enamel without causing any obvious pulp damage[9,10]. However, if more than one heating cycle was necessary to remove ceramic brackets, pulpal tissue damage did occur. There has been no previous study related to the effect of electrothermal debonding of metal or ceramic brackets from ceramic veneer surfaces on the underlying pulp.

The purpose of this study was to compare three different debonding techniques [Howe pliers (H), lift off debracketing instrument (LODI)(3M Unitek, Monrovia CA), and electrothermal technique (ETD™)("A" Company, San Diego CA)] for the production of veneer damage, and to compare temperature rises in the pulp chamber when ETD was used to debond metal [ETD(M)] and ceramic [ETD(C)] brackets. Any significant temperature increase could create further potential pulpal trauma to an already traumatized tooth, increasing risk of pulpal pathosis.

2.2 Materials and Methods

2.2.1 Sample Selection

Acceptance criteria for 96 teeth required the absence of restorations or obvious enamel defects and fractures. Each tooth was transilluminated and examined under x20 magnification to detect such structural faults.

Following extraction, teeth were stored in a 1% solution of sodium hypochlorite for 24 hours prior to being pumiced for the removal of stain, debris and periodontal tissue, and then finally transferred to water.

Randomization

A computer-generated randomization list determined experimental groups to which each mounted sample was assigned (see Table 1).

2.2.2 Tooth and Veneer Preparation

Acrylic bases were fabricated in a manner that would permit convenience of handling during tooth preparation, veneer cementation and subsequent laboratory procedures (Figure 1). Bases were coded for identification and returned to the water bath for storage until the time of veneer preparation.

Each specimen had standardized tooth preparation carried out by the same prosthodontist, using diamond burs from the Brasseler Laminate Veneer System Set 4151 (Brasseler Canada®, Montreal, PQ). Initial enamel reduction was accomplished using a 0.5 mm depth gauge bur (LVS-2), with final reduction being completed with a rounded chamfer bur (LVS-3 or LVS-4). Margin preparations extended apically approximately 1.5 mm short of cemento-enamel junction and wrapped 1.5 mm beyond the occluso-buccal line angle. Preparation was followed by examination of all specimens under x20 magnification using methylene blue stain for detection of dentin exposure and/or enamel fractures.

Final impressions of each tooth preparation were obtained with a polyvinyl siloxane impression material (Express™, 3M Dental Products Division St. Paul, MN) contained within individual trays. Tooth specimens were placed into the water bath until veneer cementation.

Ceramic restorations were constructed by a commercial dental laboratory using the refractory die technique and Mirage dental ceramic (Chameleon Dental Products, Inc., Kansas City, Kansas). Initial ceramic contours were dictated by the anatomical form of each tooth and the preparation outline. It was requested that veneers be fabricated to 0.50 mm in thickness. Measurements at five different locations on each veneer recorded, with the mean value being 0.5 ± 0.06 mm (Appendix 1). Mean thickness' for individual groups were 0.49 mm for ETD(C) and Howe pliers, and 0.50 for ETD(M) and LODI.

Table 1: **Experimental Groups**

	Ceramic Brackets	Metal Brackets		
Debonding method	EC	EM	H	L
n	24	24	24	23*

EC = electrothermally debonded ceramic
EM = electrothermally debonded metal
H = debonded with Howe pliers
L = lift off debonding instrument   * = one of the original 24 samples delaminated

2.2.3 Bonding Protocol

Ceramic Veneer

The enamel surface of each tooth was dried and then etched with a solution of 37% phosphoric acid for 30 seconds followed by rinsing with water and drying with warm air. A thin layer of unfilled resin was applied to both the enamel and inner surface of the silane-treated ceramic veneers (3 layers of 3M Scotchprime Ceramic Primer). Each veneer was coated with a layer of composite resin (Mirage FLC™), and seated into position on the tooth by a single operator, as recommended by Sorenson[11], and Fox and McCabe[12]. Excess bonding material was removed with a brush coated with unfilled monomer resin prior to final light curing for 120 seconds (3M Unitek® Ortholux® XT Visible Light Curing Unit, 3M Dental Products).

Etching of Veneer

The buccal surface of veneers corresponding to the region of bracket placement were treated with Porcelock® (Den-Mat® Corp., Santa Maria, CA), a 2.5% hydrofluoric acid gel, for 180 seconds. This was followed by a 20 second wash and 20 seconds of drying with warm air free of oil/moisture. Veneer surfaces were examined for a slightly frosted appearance (similar to etched enamel) prior to application of silane.

Orthodontic Brackets and Adhesive

Starfire® ceramic brackets comprised one experimental group, while Ormco® Mini-V metal brackets were used for the other three groups. The groups associated with these brackets are illustrated in Table 1.

Rely-a-bond® (Reliance, Inc., Itasca, IL), a one-paste no-mix system, was used in conjunction with a priming agent (Scotchbond™ Ceramic Primer®) for orthodontic bracket bonding. The central area of the ceramic veneer buccal surface was treated with Porcelock®, rinsed, and dried prior to application of three layers of silane primer (3M Scotchbond™ Ceramic Primer). Ceramic surfaces were treated and orthodontic brackets bonded. A single operator applied a layer of Rely-a-bond® primer to both the ceramic veneer and bracket surfaces and then adhesive paste to the orthodontic brackets. Brackets positioned at the ideal bracket location (bracket slot 4.0 mm from the occlusal edge) with a standardized force (400 gm via Dontrix guage). Resin flash was removed while that beneath the bracket was left to cure for 5 minutes prior to the specimens being returned to water storage.

2.2.4 Specimen Storage Conditions and Thermal Cycling

Each experimental group was placed in 37°C water for 12 hours prior to bracket debonding. Previous investigations have recommended that bonding studies include thermocycling as part of the experimental protocol.[26] Current recommendations for bonding/debonding studies suggest the mandatory inclusion of thermocycling (minimum of 500 cycles) to simulate temperatures experienced in the oral environment. This investigation thermocycled 750 cycles, between water baths of 55°C and 5°C with dwell times of 30 seconds. Samples were then returned to storage conditions for 24 hours prior to bracket removal.

2.2.5 Debonding Protocol

The "A" Company Electrothermal Debonder was designed for removal of their ceramic brackets (Starfire®) from enamel surfaces. However, the tip of the debonder has been observed to also fit Ormco® Mini-V metal brackets. The electrothermal debracketing instrument (ETD™) is a cordless rechargeable battery operated system which generates heat reportedly in the range of 232°C at its tip.[12] The heat concentrates at the tip/bracket interface and is conducted to the resin layer, allowing debonding to occur within 2-4 seconds.

The current investigation observed that debonding occurred within the initial 5 second period, at which time an audible signal is produced by the ETD™. This procedure was similar for both ceramic and metal brackets.

The lift off debonding instrument (LODI) was utilized by placing the incorporated wire over a tie wing, positioning the instrument to straddle the bracket, applying gentle force until both plastic contact surfaces rested evenly on the tooth surface, and then applying greater force until the bracket lifted off. Howe pliers were used by placing the tips diagonally at the mesial-occlusal and distal-gingival of the bracket tie wings, and applying a squeezing force to the pliers while providing a simultaneous torquing force.

2.2.6 Sites of Failure

Following debonding procedure, bracket and veneer samples were each separately evaluated by observation under a x20 magnification stereomicroscope. Results were categorized based on whether the fracture occurred primarily at the veneer/adhesive interface, bracket/adhesive interface or cohesively within the resin. Veneer samples were evaluated for surface damage by visual inspection under x20 magnification stereomicroscope, a level adequate to detect clinically relevant damage. All avulsion fractures or cracks in the ceramic surface were included in the category of veneer damage as presented in Table 2. Any adhesive remaining on ceramic following bracket removal was assessed according to the Adhesive Remnant Index (ARI). This index system, developed by Artun and Bergland[13], uses the following criteria for evaluating tooth surfaces:

Score 0 = No adhesive left on the tooth
Score 1 = Less than half the adhesive left on the tooth
Score 2 = More than half the adhesive left on the tooth
Score 3 = All adhesive left on the tooth with distinct impression of the bracket mesh

The reliability of the ARI was tested by analysis utilizing Bioscan® Optimas™ (Edmonds, WA). This computer program included photographic enhancement which allowed the operator to digitize the regions of the bracket covered by resin and provided an immediate reading of the area involved. This was then computed as a percentage of the surface area of the bracket base (Appendix 2).

Veneer surfaces were evaluated and scored on a scale of 5 to 1 according to the ARI utilized by Bishara and Trulove[15]. A value of 5 indicated that no composite remained on the tooth; 4, less than 10% composite remained; 3, more than 10% but less than 90% composite remained; 2, greater than 90% composite remained; 1, all composite remained on the tooth.

Veneer damage was recorded as being absent, or present when a break in the glazed surface was observed in association with avulsion fractures or crazing of the ceramic. Clinical judgement determined the extent of veneer damage as being repairable or non-repairable.

2.2.7 Intra-pulpal Temperature Changes Due to ETD™

A K-type thermocouple probe (John Fluke® Mfg. Co., Palatine, IL) passing through a 3mm lingual access opening, was positioned on the buccal wall of the pulp chamber transversely and vertically adjacent to the bracket location (Figure 1) and stabilized with composite resin. The pulp chamber was filled with silicone oil medium, as advocated by Sheridan[10], to aid heat transfer should the thermocouple probe have been inadequately positioned. A microprocessor-based digital thermometer (calibrated by the manufacturer) recorded any temperature rise at the buccal wall during the electrothermal debonding procedure. The K-type thermocouple had a measurement range of -200°C to 1370°C with initial tolerances of ± 1.1°C over a range of 0°C to 260°C (traceable to NBS standards).

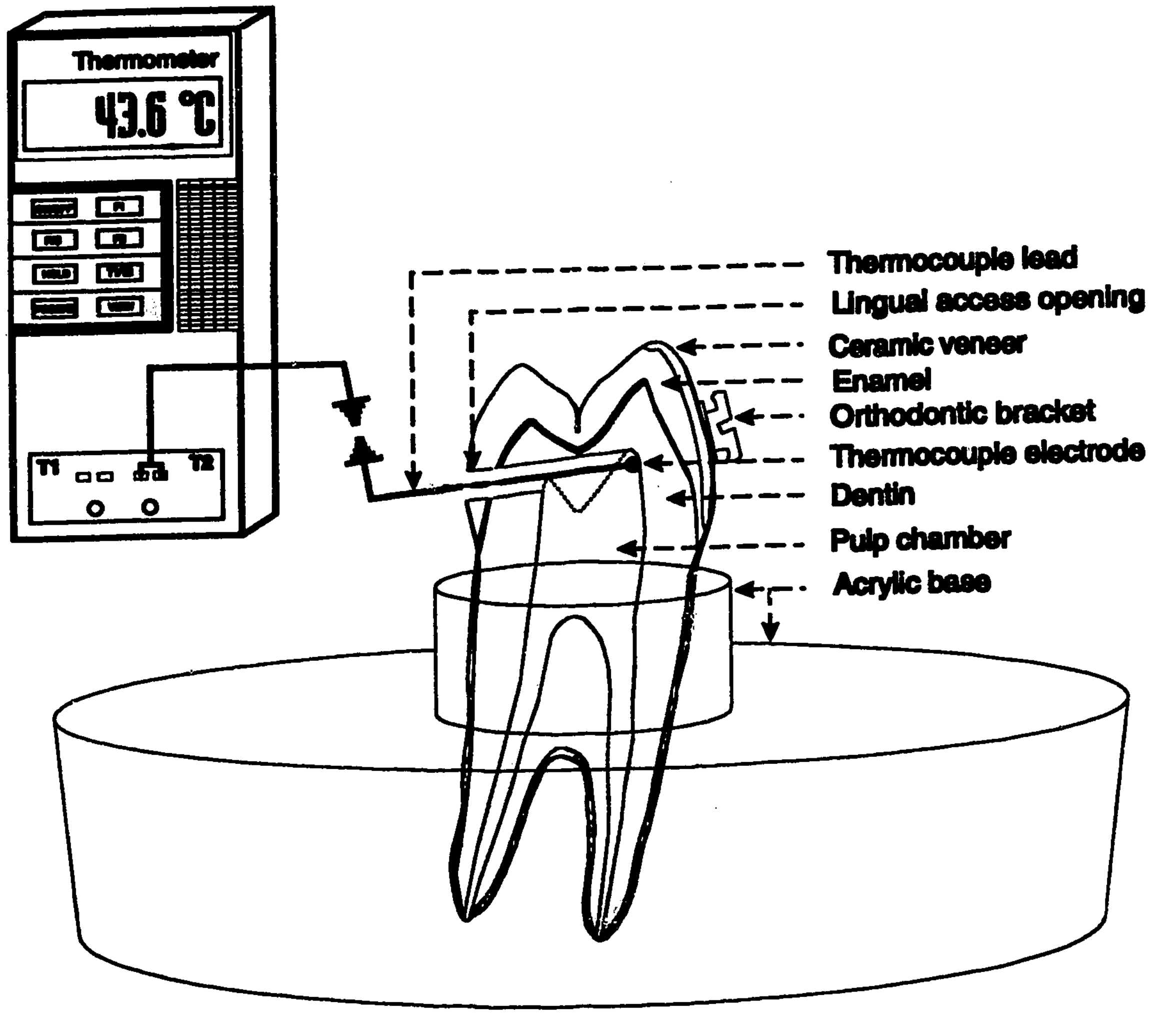


Figure 1. Schematic Diagram of Electronic Thermometer and Tooth Mounting

2.2.8 Statistical Analysis

All data were edited and verified. Comparisons between groups were done by analysis of variance (ANOVA) followed by a Scheffè multiple comparison test if there was a significant difference overall ($p<0.05$). Comparison between ETD(M) and ETD(C) temperatures was done by a t-test. Because of concerns with over testing the dataset (multiple testing), use of several varibles that are theoretically strongly related, accuracy of values for the data set, and the fact that determining relationships was a tertiary hypothesis, it was decided to set a stringent level ($p<0.001$) to determine significance.

2.3 Results

Preliminary adjuncts of this investigation included the determination of ceramic veneer thickness (Appendix 2) and ETD™ tip temperature (Appendix 3).

Mean veneers thickness was 5.0 ± 0.06 mm with a range of 0.2 mm in a single sample to a high of 0.70 mm. The average of 5 thickness measurements was 0.32 to 0.66 mm.

The mean temperature of the debonding tip was 184°C following a 5 second period of activation (251 trials) with a range of 170.3°C to 201°C. Temperatures following 10 second activations averaged 213°C (204 trials) with a range of 193.3°C to 229.8°C. All electrothermally debonded brackets were removed within the first five seconds of tip activation. Results of all debonding techniques are presented in Table 2.

Table 2: **Debonding characteristics by group**

	ETD(C) (EC)	Howe (H)	LODI (L)	ETD(M) (EM)	Sig. Diff.*
Ave. veneer thickness	0.49 mm	0.49 mm	0.50 mm	0.50 mm	NS
% resin on bracket	49%	27%	44%	80%	EM vs EC, H, L
Resin score - veneer	2.2	1.5	2.1	3.5	EM vs EC, H, L
Veneer damage	0	21%	35%	13%	EC vs L
ETD pulp temp. incr.	3.6°C	N/A	N/A	6.6°C	*
# ETD samples exceeding threshold temp. (5.5°C)	2/24 (8%)	N/A	N/A	11/23 (48%)	*

* = significance level .05

Each experimental group began with a sample size of 24. During the experimental procedures outlined by the protocol, one specimen in the LODI group had the veneer delaminate. As a result the LODI group was left with an n=23 and the experimental population with a total of 95 specimens.

None of the ETD(C) veneer samples were damaged as a result of the debonding procedure. Removal of metal brackets by all techniques tested, lead to the following rates of damage: ETD(M) 3 (13%); Howe pliers 5 (21%); LODI 8 (35%). All sites involved damage which would warrant refinishing of the veneer. In only 3 cases were the samples damaged to a point where replacement of the veneers may have been necessary in a clinical situation due to esthetics. All 3 cases were from the Howe plier group.

Comparisons

Table 2 lists results of the veneer thickness, ARI, rate of damage for each of the four experimental groups, as well as the pulp temperature increase for the ETD™ groups. Veneer thickness was recorded at five specific locations (the average of the five measurements for each sample), and there was no significant difference (p<0.05) between groups as determined by an analysis of variance (Appendix 4).

The ANOVA followed by a Scheffè analysis determined those pairs of groups significantly different ($p < 0.05$) for ARI and veneer damage. Analysis of the ARI values (Table 2) indicated that ETD(M) had significantly greater resin remaining on the bracket base following debonding than metal brackets debonded with Howe pliers or LODI. ARI scores for ETD(M) was also significantly greater than that for electrothermally debonding ceramic brackets. There were no significant differences between any other pairs. ETD(M) had the greatest amount of resin remaining on the bracket (80%) and Howe pliers the least (27%). Comparison between results of ARI methods confirms the reliability of estimated values for either bracket or veneer (see Appendix 2).

Comparison of veneer damage between groups showed that ETD(C) was significantly different than debonding with LODI (p<0.05), but that there was no difference between all other pairs. Clinically identifiable veneer damage was observed via x20 magnification, and occurred with an incidence of 35% for the LODI group, followed by Howe pliers at 21% and ETD(M) at 13%. ETD(C) had no cases of veneer damage. These values were both clinically and statistically significant. Typical veneer damage involved regions of thin avulsion fractures as illustrated in figure 2.

There was a significant difference ($p<0.05$) between changes in temperature at the pulp wall of electrothermally debonded ceramic brackets (3.55°C ± 1.20°C) and metal brackets (6.55°C ± 3.81°C). Threshold temperature for irreversible pulp damage was exceeded by 8% of the ETD(C) group and 48% of the ETD(M) group ($p<0.05$). This has clinical significance in that ETD(C) runs a minimal risk of causing pulp damage, while ETD(M) may cause such damage approximately one half of the time.

Sites of failure at debonding are summarized according to group in Table 3. The site of bond failure for the ETD(C), Howe plier and LODI groups was at bracket/resin interface approximately one half of the time, and split between the veneer/resin site and cohesively within the resin the remainder of the time. ETD(M) specimens demonstrated failure at the veneer/resin interface in 77% of cases, with the remaining cases failing at the bracket/resin interface and cohesively at similar rates. Application of the ANOVA followed by a Scheffè analysis demonstrated significant differences between groups for all failure sites. Bracket/resin and veneer/resin failures each demonstrated significant differences between ETD(M) and Howe pliers, LODI, ETD(C). Cohesive resin failures demonstrated significant differences only between Howe pliers and ETD(M) and LODI.

Table 3: **Failure Site by Group**

	Bracket/Resin (%)	Cohesive (%) (within resin)	Veneer/Resin (%)
ETD™(C)	52	18	30
ETD™(M)	13	10	77
Howe Plier	60	30	10
LODI	48	28	24

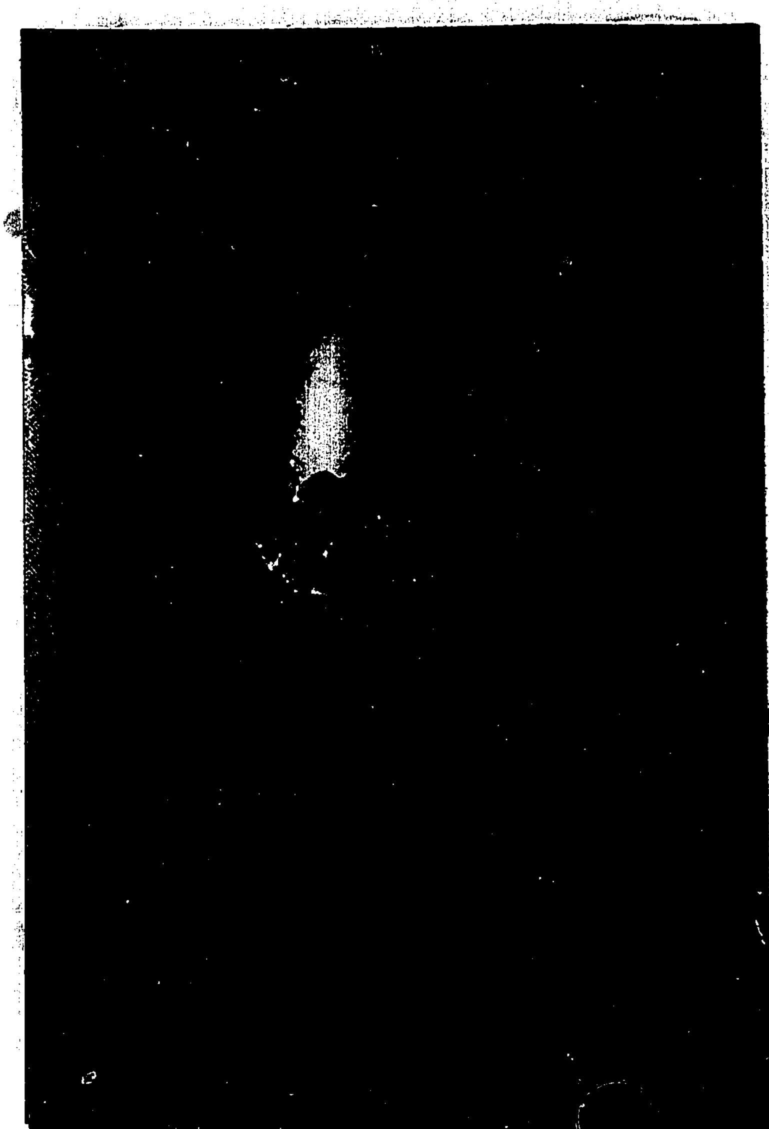


Figure 2. Typical ceramic veneer avulsion fracture (repairable) due to debonding of metal brackets.

Figure 3. Irrepairable ceramic veneer avulsion fracture and cracking due to debonding of metal brackets with Howe pliers.

2.4 Discussion

Veneer Damage

This study examined surface damage incurred by ceramic veneers during debonding of orthodontic brackets. A relatively constant veneer thickness was established, with no significant difference between groups [mean of 0.50 ± 0.06 mm ($p<0.05$)]. The refractory die technique of veneer fabrication allows the veneer thickness to be checked only once complete, but less distortion occurs than with platinum foil technique.[16,17]

The present study included constant veneer thickness to preclude fractures due to differences in bulk of material. Veneer damage was associated with all three techniques of debonding metal brackets. Surface damage was identified as any avulsion fracture or crack of the veneer. The majority of these defects, although detectable to the unaided eye, would be considered slight and could be easily refinished/polished with diamond impregnated polishing wheels and paste. It was determined that 3 of the defects, all from the Howe plier group, were severe enough to possibly warrant clinical replacement of the restoration. Such damage is evident in figure 3. Mechanism of action for the Howe plier is to distort the bracket base to the point that the mechanical retention with the resin is broken. The clinical forces involved are the least consistent when compared to other debonding techniques. Although the LODI produces a greater overall rate of veneer damage the extent of damage is less severe and consistently repairable.

ETD(C) was not associated with any veneer damage, while debonding metal brackets produced results as follows: ETD(C) 0%; ETD(M) 13%; Howe pliers 21%; LODI 35%. This may indicate that tensile forces are potentially more damaging than shearing or peeling forces. Debonding with Howe pliers produces a shear peel force, while the LODI produces a tensile force. ETD™ is generally associated with a torquing force during bracket removal. A previous investigation found that tensile forces applied to resin disks bonded to ceramic veneers produced veneer fractures in all cases.[18] The current investigation also observed this trend, though not to the same magnitude.

Site and mode of bond failure may also determine the degree of veneer damage that should be expected. Electrothermal debonding tends to occur when the resin beneath the bracket has been sufficiently denatured. The difference in sites of failure between metal and ceramic brackets may be attributed to bracket design and material composition.

The Starfire® ceramic bracket has a smooth base and relies on chemical interaction for its adhesion, whereas metal brackets have a meshwork pad which enables mechanical adhesion to occur. Thus, if the ETD™ acts by denaturing the chemical composition of the resin, it might be expected to result in significant failure of ceramic bracket adhesion at the bracket/resin interface. Indeed, this was the site of failure 52% of the time for ceramic brackets and only 13% of the time for metal brackets. Metal brackets failed at the veneer/resin interface at a rate of 77%, possibly due to a chemical denaturing of the resin at that site while still maintaining the mechanical link at the bracket/resin interface. This finding is similar to that of Rueggeberg and Lockwood[19], who found that debonding metal brackets at room temperature produced failure rates 80% at the bracket/resin interface and 20% within the enamel, compared to 187°C where the site of failure shifted toward the tooth/resin interface in 70% of cases. For 22 of 24 samples in ETD™ (M) group it was observed that site of failure at the veneer/resin interface occurred at a centralized location corresponding to the area adjacent to the greatest heat application. Electrothermally debonding ceramic brackets from enamel have been shown to occur at the bracket/resin interface in 80% of cases.[20] A proposed explanation is that the site of failure involves the silane layer, either with its reaction with ceramic or resin. Studies have suggested that site of failure will vary between different types of ceramic brackets.[21] It appears that such differences may be due to varying means of retention (ie. chemical versus mechanical versus chemical/mechanical).

ARI was determined using three separate techniques, all of which produced similar results. One of these systems utilized a computer software package which relied on input based on an operator's estimate of 'best fit'. Cost-benefit analysis of the highly specialized and expensive Optimas™ program suggests that the results it provides are not any more accurate than ARI techniques previously utilized.[14,15,22]

Intra-pulpal Temperature Increase

The objective of the second part of the study was to determine the temperature created at the buccal wall of the pulp as result of debonding. Sheridan *et al.*[10] have determined that temperatures involved with the ETD™ are safe to the pulp, with increases being less than 1°C if a water spray was used. Brouns *et al.*[21] reported that the average pulp temperature rise for debonding ceramic brackets varies from 1.1°C to 5.2°C depending on type of electrothermal debonder used. In the present study, ETD(C) occurred with an intrapulpal temperature rise of 3.5 ± 1.2°C, while metal bracket removal occurred with a temperature increase of 6.5 ± 3.8°C. The presence of a large variation is recognized for metal brackets. This can only be explained by a small number of outliers which were beyond 2 standard deviations. It is recognized that the temperature noted by Zach and Cohen[23] as the threshold for pulpal damage was 5.5°C in primates. While the ETD(M) may have resulted in fewer cases of veneer damage, the thermal insult must be examined with respect to the potential for inflicting injury to the pulp and possible delamination of the veneer. The metal bracket group had 11 of 24 samples (46%) exceed the threshold temperature, while only 2 of 24 (8%) in the ceramic bracket group exceeded this level. A possible explanation may be due to differences involved between mechanical and chemical means of adhesion and materials involved. The ceramic bracket tends to act as an insulator, permitting a gradual temperature increase to occur until failure at the bracket/resin interface.

Since bracket/resin interface and cohesive failure account for 70% of sites involved with ETD(C) greater amounts of resin remain on the tooth, providing a further insulating factor. Metal brackets conduct heat and may result in greater temperature diffusion through the resin material before failure occurs at the veneer/resin interface. Since it appears that a greater degree of heat may be present at the veneer surface, pulp temperatures may increase accordingly. The debonding temperature associated with Rely-A-Bond™ at the tooth/resin interface has been confirmed previously as 154°C.[24]

Future Investigations

"A" Company has recently developed an updated version of the ETD™ which operates by AC electricity versus batteries. Dentaurum® has recently discontinued their line of electrothermal debonders. Future investigations should utilize the new "A" Company model to measure heat produced at the tip, intrapulpal temperature increases, and time required to debond. The sites of failure associated with different bonding materials and different esthetic brackets should also be pursued. Effects of microetching with and without the use of hydrofluoric acid on ceramic veneers should also be investigated. Comparisons of debonding techniques should also include debonding pliers.

2.7 Conclusions

The first purpose of this study was to compare the efficacy of three different debonding techniques of debonding orthodontic brackets from ceramic veneers without damaging veneer surfaces. Results indicated that all forms of debonding metal brackets produced some degree of veneer surface damage. Rates of veneer damage were 13% with ETD™(M), 21% with Howe pliers, and 35% with LODI. No damage occurred in association with ETD™(C).

The second purpose of the study was to determine whether pulp chamber temperature increases associated with electrothermally debonding either ceramic or metal brackets exceeded the previously published threshold level of 5.5°C for primates. Results indicated that the mean temperature increase associated with ETD(C) is 3.5°C and that of ETD(M) is 6.5°C. Only 8% of ETD(C) samples exceeded the threshold while 48% of ETD(M) samples exceeded the threshold. Electrothermal debonding of ceramic brackets from ceramic veneers appears to be a safe procedure, both in terms of avoiding veneer damage and pulpal temperature increase exceeding the threshold for development of pulpal pathosis. However, electrothermal debonding of metal brackets without air or water coolant appears to be damaging to both veneer surfaces and potentially to the pulp.

The practicing orthodontist may be presented with situations requiring bonding of brackets to ceramic veneers. Both ceramic brackets treated with silane and metal brackets will provide a reliable and predictable bond to ceramic surfaces when treated with silane. The results of this study suggest that metal brackets cannot be predictably debonded without producing either veneer damage if debonded mechanically or electrothermally, or potential pulp damage if debonded electrothermally. Ceramic brackets may be removed without causing either veneer or pulpal damage if debonded electrothermally. The current recommendation for bonding to a ceramic veneer is to place a ceramic bracket which may be subsequently electrothermally debonded. Metal bracket removal should be accomplished with a lift off debonding instrument followed by careful removal of residual resin and refinishing/polishing of the veneer.

Acknowledgments

This study was supported by the McIntyre Research Fund, the Canadian Fund for the Advancement of Orthodontics, and generous donations from the following companies within the private sector:

Aurum Ceramic Dental Laboratories

"A" Company

Ormco

REFERENCES

1. Proffit WR, Fields HW: Contemporary Orthodontics 2nd Ed. Mosby Year Book, Inc. St. Louis. 1993

2. Alexander RG: The Alexander Discipline. Edited by Gary A. Engel. Published by Ormco® Corporation 1986

3. Bell RD, Faulkner RA, Lee-Knight CT, Schneider VE, Towriss BD: Bimaxillary and Standard Mouthguards and Their Effect on Football Performance. The Canadian Athletic Therapists Association Journal. 1991 Issue. pp16-8

4. Lee-Knight CT, Bell RD, Faulkner RA, Schneider VE: Protective Mouthguards and Sports Injuries. Canadian Dental Association Journal. 1991;57:39-41

5. Z achrisson BU: Solutions to Difficult Bonding Problems. Scientific Lecture at 95th American Association of Orthodontists Annual Session. May 15, 1995

6. Kao EC, Boltz KC, Johnston WM Direct bonding of orthodontic brackets to ceramic veneer laminates. Am.J.Orthod.Dentofac.Orthop. 1988;94:458-468

7. Kao EC, Johnston WM: Fracture incidence on debonding of orthodontic brackets from ceramic veneer laminates. J.Prosth.Dent. 1991;66:631-7

8. Smith GA, McInnes-Ledoux P, Ledoux WR, Weinberg R: Orthodontic bonding to ceramic -- bond strength and refinishing. Am.J.Orthod.Dentofac.Orthop. 1988;94:245-52

9. Jost-Brinkmann PG, Stein H, Miethke RR, Nakata M. Histologic investigation of the human pulp after thermodebonding of metal and ceramic brackets. Am.J.Orthod.Dentofac.Orthop 1992;102:410-7

10. Sheridan JJ, Brawley, Hastings J: Electrothermal debracketing Part I. An in vitro study. Am.J.Orthod. 1986;89:21-7

11. Sorensen JA, Strutz JM, Avera SP, Materdomini D: Marginal fidelity and microleakage of ceramic veneers made by two techniques. J.Prosthet.Dent. 1992;67:16-22

12. Fox NA, McCabe JF: An Easily Removable Ceramic Bracket? Br.J.Orthod. 1992;19:305-9

13. Jost-Brinkmann PG, Stein H, Miethke RR, Nakata M. Histologic investigation of the human pulp after thermodebonding of metal and ceramic brackets. Am.J.Orthod.Dentofac.Orthop 1992;102:410-7

14. Artun J, Bergland S: Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am.J.Orthod.Dentofac.Orthop. 1984;85:333-40

15. Bishara SE, Trulove TS: Different debonding techniques for ceramic brackets. Comparisons of different debonding techniques for ceramic brackets: An in vitro study
Part I. Background and methods. Am.J.Orthod.Dentofac.Orthop 1990;98:145-53

16. Sheets CG, Taniguchi T: A multidie technique for the fabrication of ceramic laminate veneers. J.Prosthet.Dent. 1993;70:291-5

17. Sheets CG, Taniguchi T: Advantages and limitations in the use of ceramic veneer restorations. J.Prosthet.Dent. 1990;64:406-11

18. Simonsen RJ, Calamia JR: Tensile bond strength of etched ceramic. J.Dent.Res. 1983;62:297.

19. Rueggeberg FA, Lockwood P: Thermal debracketing of orthodontic resins. Am.J.Orthod.Dentofac.Orthop 1990;98:56-65

20. Bishara SE, Trulove, TS: Comparisons of different debonding techniques for ceramic brackets: An in vitro study. Part II. Findings and clinical implications. Am.J.Orthod.Dentofac.Orthop 1990;98:263-73

21. Brouns EM, Schopf PM, Kocjancic B: Electrothermal debonding of ceramic brackets. An in vitro study. European Journal of Orthodontics. 1993;15:115-23

22. Gaffey PG: Bond Strength of Thermally Debonded, Rebonded Ceramic Brackets. M.Sc. Thesis, University of Alberta, Edmonton, Alberta. Spring 1994

23. Zach L, Cohen G: Pulp response to externally applied heat. Oral.Surg.Oral.Med.Oral.Pathol. 1965;19:515-30

24. Rueggeberg FA, Lockwood PE: Thermal debracketing of single crystal sapphire brackets. The Angle Orthodontist. 1992;62:45-50

Chapter Three

General Discussion and Recommendations

3.1 General Discussion

Developments in materials sciences have resulted in restorative options such as porcelain veneers, requiring minimal tooth reduction and providing good long-term esthetics and function. The introduction of bonding into dentistry brought with it not only the benefits of exceptionally high quality esthetics, but also previously inexperienced problems with technique sensitive materials. One such problem, related to orthodontics, has been bonding to surfaces other than enamel. Developments such as micro-etching, acid etching, intermediate resins, and silane primers have all contributed to improved bonding of orthodontic brackets to restorative ceramics and metals. Although much previous work has been completed with regard to bracket bond strength, ceramic damage with debonding, and ETD™ effects on the pulp, few studies have involved ceramic veneers. Previous research may be criticized for making conclusions about dental ceramics in general, when methodology may have involved different types of ceramics of varying thicknesses. Studies evaluating bond strengths have consistently used an Instron testing apparatus, usually applying either shear or tensile forces. Although such data are important for in vitro comparisons between groups, it does not closely represent clinical conditions or techniques. This study utilized clinical debonding techniques, assuming that previous in vitro findings have been accurate. A continually repeated question in orthodontics today is, "What is the most appropriate method of debonding ceramic brackets from ceramic veneers?". The present study has investigated this question, looking specifically at veneer surface damage, and pulpal temperature changes associated with electrothermal debonding.

An attempt was made to maintain a research design with as high a level of integrity as possible. A critique of the design leads to positive suggestions in a number of areas, which should be considered for future studies. The sample size estimate was determined by a review of similar types of studies appearing in the literature. Although each experimental group in this study had an n=(24) much higher than the average found in the literature (n=13), it could have been somewhat larger itself. An n=30 would be considered statistically much stronger, while optimally one would strive for 40-50 per group. In this particular case the pilot project was utilized primarily to determine correctness of protocol and armamentarium, not to determine sample size.

The current investigation attempted to control a number of factors which were subsequently presumed to be constant. Despite this, several sources of error exist in the methodology. Ninety-six extracted maxillary first bicuspids, free of restorations and caries, made up the experimental population. The statistical strength of the study was possible due to adequate numbers within each experimental group. Optimally, it would be desirable to include as many bonding materials and debonding techniques as possible. Techniques omitted were debonding pliers and cutters. However, availability of specimens, time, and funding limit the parameters of any investigation.

Teeth restored with ceramic veneers in contemporary practice most often include maxillary anteriors and first bicuspids. An attempt was made to select specimens with crowns of similar size and shape. Each specimen had a standardized tooth preparation carried out by a single prosthodontist. However, a potential source of error in evaluating intra-pulpal temperature changes was the difference in remaining tooth structure (enamel and dentin) between samples. Specimens were collected from a number of sources, and no differentiation was made according to age of the donor. Wheeler[1] noted that a pulp cavity may be large, as in young individuals, or it may be shrunken and constricted by excessive formation of secondary dentin; or there may be calcification within the pulp tissue itself. Although the thickness of the veneer was controlled, that of the remaining tooth structure was unknown. Thicker specimens in the ETD(M) group may have presented with lower than average temperature rises, while thinner specimens may have experienced higher than average temperature rises due to differences in 'insulation'.

Randomization of teeth into treatment groups resulted in partial blinding of the project. Codes identifying treatment conditions for the metal bracket groups were not revealed until the time of debonding. Thus, at the time of bonding, the clinician was aware of only one treatment group -- that involving ceramic brackets. Bonding occurred a group at a time to ensure identical thermocycling conditions. Following thermocycling and just prior to debonding, codes identifying treatment groups were broken. A purer method would have been to randomize samples between groups prior to thermocycling. However, it was desired that all samples be stored for similar time periods after bonding prior to thermocycling and debonding in order to avoid creating a non-constant variable of storage time.

Veneers were seated into position on the tooth by a single operator using dual cured bonding resin. In one case the operator questioned whether accurate seating of the veneer had occurred; that sample failed during subsequent procedures. All other specimens were assumed to have been uniformly bonded.

Ceramic veneers were fabricated by a commercial laboratory using the refractory die technique. This technique has become the industry standard due, in part, to the accuracy of fit of the final product. However, a drawback with respect to the current investigation was the need to have a constant veneer thickness. Ceramic thickness cannot be determined until the restoration has been completed. Protocol required that the mid-buccal surface of the veneer have a mean thickness of 0.5 mm, as me[illegible]a crown and bridge caliper. Measurements of each specimen were then average[illegible]ages then combined to obtain mean of 0.50 ± 0.06 mm. Reproducibility was determined within the previously conducted pilot project. Pilot project trial results indicated high degrees of inter- and intra-operator reproducibility.

A single operator bonded all orthodontic brackets to veneers with a standardized force (400 gm). However, differences in contour of the buccal surfaces of the veneers may have led to differences in resin thickness beneath individual brackets. Knoll *et al.*[2] noted that regions of thicker resin result in greater polymerization shrinkage and internal stresses due to differences in coefficients of thermal expansion/contraction.

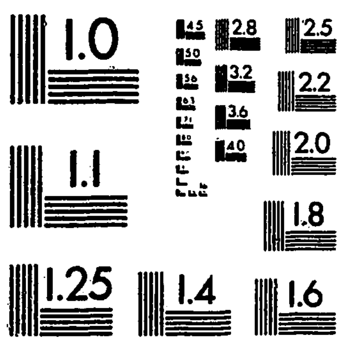
Products used in the bonding process were constants: Porcelock™ Porcelain Etching Solution (2.5% hydrofluoric acid), 3M Scotchbond™ (silane agent), and Rely-a-bond® (no mix orthodontic adhesive). The majority of studies in the literature have used 9.6% hydrofluoric acid. However, a common criticism relates to the potential hazards of using such a concentrated solution intraorally. In SEM studies, Porcelock has been observed to produce extremely micro-porous surfaces,[3] and shear bond strength to ceramic surfaces of 12.40 ±

3.04 MPa.[4] Other product combinations may be as effective, but would necessitate an investigation much larger in scale. It may be that various bracket/silane/resin combinations produce widely varying intra-pulpal temperatures with ETD™. Definitive results could provide recommendations regarding the most desirable combinations to achieve debonding temperatures safe to the pulp. Actual bond strengths were not measured in the current study, keeping debonding techniques as clinically relevant as possible. A procedure not included in the protocol of most bonding/debonding studies is use of the micro-etcher. Its use has been recommended to bond to most contemporary restorative materials.[5] Zachrisson and Buyukyilmaz[6] noted that etching of glazed porcelain produces less prominent micromechanical patterns than micro-etching by aluminum oxide sandblasting. In addition, micro-etching does not produce microfractures as occurs with mechanical grinding with a green stone. Zachrisson[5] reported bond strengths of 11.9 MPa associated with micro-etching, silane and All-Bond2 intermediate resin, and 11.8 MPa with micro-etching and silane (and bonded with Concise resin). Suliman *et al.*[7] determined that micro-etching was not as effective as mechanical roughening combined with hydrofluoric acid etching for porcelain repair systems. The current investigation did not include micro-etching in the protocol, but would recommend future studies do so.

Zachrisson[5] stated that it is essential for bonding/debonding studies to include thermocycling as part of the experimental protocol. He suggested that a minimum of 500 cycles between the temperatures of 5°C-55°C are required to realistically simulate temperatures in the oral environment. Previous investigation have supported this view and

2 OF/DE 2

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT



PRECISION[SM] RESOLUTION TARGETS

included thermocycling as part of their experimental procedure.[8-12] The rationale for including thermocycling in experimental protocol is to simulate the extreme intra-oral temperatures normally tollerated. Selected early cases found no significant difference in the bond strength of glazed and deglazed ceramics following thermocycling of samples.[13] However, this is in contrast the majority of more contemporary studies which have found thermocycling to reduce the bond strengths of silane systems.[11,14,15] The current investigation satisfied the criterion of thermocycling, having been alternated 750 cycles between 5°C-55°C. A review of previous investigations determined that the bond strength is decreased not only by thermocycling but also by long-term storage in water.[15] Therefore, once brackets were bonded, the current study permitted storage for a period of only 12 hours (at 37°C) prior to thermocycling, and then 24 hours prior to debonding.

The consistency of temperature produced by the ETD™ tip was questioned prior to conducting the experiment. To determine the presence of any such variation, ETD™ batteries were fully charged and the temperature at the debonding tip recorded for as many trials as the life of the battery would permit. Recordings were made following 5 second tip activations for each of two batteries, and then again following 10 second tip activations for each of the two batteries (Appendix 2). Mean temperatures produced following both 5 and 10 second ETD™ activations were found to be consistent when batteries held adequate charge. The ETD™ unit provides an audible warning signal when the battery charge is inadequate. At 5 second intervals battery #1 had a mean of 184.8 ± 5.4°C with a minimum of 172.8°C and a maximum of 201.3°C (135 trials), while battery #2 had a mean of 183.2 ±

5.1°C with a minimum of 170.3°C and a maximum of 195°C (116 trials). At 10 second intervals battery #1 had a mean of 214.9 ± 6.5°C with a minimum of 193.4°C and a maximum of 229.8°C (107 trials), while battery #2 had a mean of 211.5 ± 5.6°C with a minimum of 197.1°C and a maximum of 223.4°C (97 trials). Although at the time of writing the newly-developed alternating current ETD™ model is only in a prototype, it is expected to have much more consistent debonding temperatures than the battery-operated model.

The current study found mean intra-pulpal temperature increases of 3.5°C and 6.5°C associated with ceramic and metal brackets respectively. These were compared to the threshold temperature of 5.5°C where irreversible pulp damage has been reported to occur. It has been suggested that the possibility of pulpal damage may be minimized by using no-mix resins systems, since they demonstrate a lower mean debonding temperature than do two-paste systems.[14] In addition, it has been shown that as the organic filler content of the resin decreases, the debonding temperature also decreases. Rueggeberg and Lockwood[14] noted that no-mix resins are less fully cured than two-paste systems, so require a lower temperature for debonding. This being the case, clinicians would be wise to use a no-mix system over a two-paste system of similar filler content. Sheridan[46] deomonstrated that use of water spray as a coolant immediately following the electrothermal debonding procedure minimizes the intrapulpal temperature rise to 0.8°C.

Few studies have recorded debonding forces associated with the ETD™. Although the mode of action relies on resin denaturing to create bond failure, there is a twisting/tensile force involved with the process. As individual bond strengths vary, so will the clinical forces necessary for bracket removal. This was a component of the investigation impossible to control, not only for the ETD™ but also for the Howe pliers. An attempt was made to maintain as constant a debonding technique as possible, for all procedures.

Clinical recommendations are based on the findings of the current investigation. When the orthodontist is faced with the situation of bonding to a ceramic veneer he/she must consider whether a single unit or multiple restorations are involved. The presence of multiple restorations magnifies the importance of the decision regarding the types of materials and instruments used to bond and debond. Should debonding result in physical damage to one of two (or more) neighbouring veneers, it is sometimes very difficult to recapture the original esthetics. Conspicuous cracks or fractures occurring within ceramic veneers are obviously complications which should be avoided if at all possible. Results of this study indicate that the bracket of choice when bonding to veneers would also be ceramic. There were no veneers damaged as result of electrothermally debonding ceramic (Starfire®) brackets, while damage was associated with each of the three methods of debonding metal brackets. The method with the highest rate (35%) of veneer damage was the LODI. However, all cases of damage (8) were minor in nature, and could be refinished to a clinically acceptable result with diamond impregnated polishing disks. Howe pliers had only 5 cases (21%) of veneer damage, but three of the five were conspicuous in nature. At least one veneer would have been replaced in a clinical situation while the other two would depend on the position and visibility in the mouth, with refinishing being a possible result. ETD(M) was associated with three cases (13%) of veneer damage, all minor in nature and repairable. The prudent clinician should be aware of the risk associated with debonding metal brackets, but that the rate of irreparable damage is small (1-4% in this study). They should be more concerned with the occurrence of temperatures beyond the threshold where irreversible pulpal damage transpires (5.5°C). The mean intra-pulpal temperature increase for metal brackets was 6.5°C with temperatures elevated beyond the threshold level in 45.8% of cases. Ceramic brackets had an intra-pulpal temperature rise of 3.5°C, with only 2 cases (8%) reaching the threshold level. One of these cases demonstrated a 5.5°C increase and the other a 5.7°C increase. Therefore, the risk involved with electrothermally debonding ceramic brackets is essentially nil.

The current study tested two main hypotheses. The first was that there was no difference in the incidence of veneer damage resulting from debonding techniques used for ceramic or metal brackets. This hypothesis must be rejected since electrothermal debonding of ceramic brackets produced no veneer damage, while all three debonding techniques tested with metal brackets resulted in damaged veneers. The second hypothesis was that there was no difference between the intrapulpal temperature produced by electrothermal debonding metal or ceramic brackets. This hypothesis was also rejected since ceramic brackets debonding produced temperature rises below the threshold for irreversible pulpal damage, while metal bracket debonding produced temperature rises above the threshold.

In summary, clinicians faced with bonding to ceramic veneers should utilize ceramic brackets, etch with hydrofluoric acid, use a silane primer and no-mix resin, and debond electrothermally. Once bracket removal is complete, remaining resin is removed and the veneer re-finished as required.

3.2 Recommendations for Future Studies

1. Shortcomings of the ETD™ have resulted in re-design of the instrument. The latest prototype has all mechanical components built into the handpiece which is now powered by alternating current. Although the debonding tip is still engineered to fit only Starfire® brackets, it has been made safer with the addition of a third wall, to reduce the risk of unintentional release of a bracket. This new instrument has the potential for more consistent performance at what has been reported to be a higher temperature. It is doubtful that higher temperatures are required for debonding. Any major change in temperatures generated by the latest generation instrument should be evaluated in a manner similar to the present study.

2. Debonding tip(s) should be modified to fit various ceramic brackets. Evaluation of ETD™ on different bracket types could lead to preferred bracket/silane/resin combinations for bonding to ceramic veneers.

3. Tooth/veneer samples subjected to ETD™ should be examined for any denaturing or weakening of the bond at the enamel/ceramic interface. Based on the findings of this study, one may speculate that ETD(C) would have no significant effect, while ETD(M) may produce some weakening, due to the different sites of failure.

4. Investigation into average dentin thickness for virgin teeth of various ages may assist in determining debonding temperatures/times deemed to be safe to the dental pulp. This could lead to guidelines for use with a consistently performing ETD™.

5. Armamentarium of the current study could be modified to include pressure

transducers to measure various debonding force vectors which may be associated with ETD™ or LODI.

6. In vivo investigations relating to inflammatory pulpal responses produced by the latest generation ETD™ could observe the results of debonding various bracket/silane/resin combinations from bicuspids scheduled for orthodontic extraction.

7. The effect of micro-etching ceramic veneers prior to HF application should be examined with reference to subsequent veneer damage at the time of debonding. The micro-etcher should also be evaluated for its ability to remove residual resin from ceramic veneers following bracket debonding as compared to other clean-up procedures (rotary instrumentation, debonding pliers, etc.).

8. Debonding techniques involving the application of cold (versus heat) should be developed and investigated to assist in understanding whether ETD succeeds by differences in coefficients of thermal expansion or by denaturing the bonding resin itself.

References:

1. Wheeler RC: Dental Anatomy, Physiology and Occlusion 5th Edition. W.B. Saunders Company, Toronto 1974

2. Knoll M, Gwinnett AJ, Wolff MS: Shear strength of brackets bonded to anterior and posterior teeth. Am.J.Orthod. Vol. 89: 476-479, 1986

3. Kondo M, Ikeda M, Takeuchi N, Kanamori K, Kamiya K, Gomi A, Asai T, Senda A: Study on the porcelain veneer restoration: Effect of various treatments of porcelain surface on the bonding strength at porcelain-resin interface. J.Dent.Sc. Vol.28 No.2 June 1990

4. Major PW, Koehler JR, Manning KE: 24 Hour Shear Bond Strength of Metal Orthodontic Brackets Bonded to Porcelain Using Various Adhesion Promoters. AJO (1995 in press)

5. Zachrisson BU: Solutions to Difficult Bonding Problems. Scientific Lecture at 95th American Association of Orthodontists Annual Session. May 15, 1995

6. Zachrisson BU, Buyukyilmaz T: Recent Advances in Bonding to Gold, Amalgam, and Porcelain. JCO. Vol.27 No.12 December 1993

7. Suliman AHA, Swift EJ, Perdigao J: Effects of surface treatment and bonding agents on bond strength of composite resin to porcelain. The Journal of Prosthetic Dentistry. Vol.70 No.8 August 1993

8. Newman SM, Dressler KB, Grenadier MR: Direct bonding of orthodontic brackets to esthetic restorative materials using a silane. Am.J.Orthod. Vol.86 No.6 December 1984

9. Klockowski R, Davis EL, Joynt RB, Wieczkowski G, MacDonald A: Bond strength and durability of glass ionomer cements used as bonding agents in the placement of orthodontic brackets. Am.J.Orthod.Dentofac.Orthop. Vol.96 No.1 July 1989

10. Smith GA, McInnes-Ledoux P, Ledoux WR, Weinberg R: Orthodontic bonding to porcelain -- bond strength and refinishing. Am.J.Orthod.Dentofac.Orthop. Vol.94 No.3 September 1988

11. Diaz-Arnod AM, Aquilino SA: An evaluation of the bond strengths of four organosilane materials in response to thermal stress. J.Prosthet.Dent. Vol.62 1989: 257-60

12. Eustaquio R, Garner LD, Moore BK: Comparative tensile strengths of brackets bonded to porcelain with orthodontic adhesive and porcelain repair systems. Am.J.Orthod.Dentofac.Orthop. 1988;94:421-5

13. Andreasen GF, Stieg MA: Bonding and debonding brackets to porcelain and gold. Am.J.Orthod.Dentofac.Orthop. 1988;93:341-5

14. Newburg R, Pameijer CH: Composite resins bonded to porcelain with silane solution. J.A.D.A. Vol.96, February 1978

15. Fan PL: Porcelain repair materials. Council on Dental Materials, Instruments and Equipment. J.A.D.A. Vol.122 No.9 August 1991

16. Rueggeberg FA, Lockwood P: Thermal debracketing of orthodontic resins. Am.J.Orthod.Dentofac.Orthop. 98:56-65, 1990

Appendices

Legend of Abbreviations:

C 3.0:	midline of veneer, 3.0 mm from its occlusal surface
C 4.5:	midline of veneer, 4.5 mm from its occlusal surface
C 6.0:	midline of veneer, 6.0 mm from its occlusal surface
(ARI BRACK) ARI Bracket:	percentage of bracket base covered with resin (Optimas)
(ARISCORE) Bracket score:	estimation of bracket base covered with resin (as per Gaffey)
(VENSCORE) ARI Tooth:	estimation of resin remaining on veneer (as per Bishara)
BR:	bracket/resin site of failure
CO:	cohesive failure within resin
VR:	veneer/resin site of failure
Treatment groups:	B = Howe Plier group D = LODI group ETD (C) = electrothermally debonded ceramic bracket group ETD (M) = electrothermally debonded metal bracket group

Appendix One

Veneer Thickness Measurements

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
1	0.5	0.5	0.5	0.5	0.5
2	0.5	0.4	0.4	0.5	0.5
3	0.6	0.5	0.5	0.5	0.5
4	0.6	0.6	0.6	0.5	0.5
5	0.3	0.3	0.3	0.5	0.5
6	0.7	0.6	0.6	0.6	0.6
7	0.5	0.5	0.5	0.5	0.4
8	0.5	0.5	0.5	0.5	0.4
9	0.3	0.3	0.3	0.3	0.5
10	0.4	0.3	0.3	0.3	0.3
11	0.5	0.4	0.4	0.4	0.4
12	0.3	0.4	0.3	0.5	0.5
13	0.5	0.5	0.5	0.5	0.6
14	0.5	0.5	0.5	0.4	0.6
15	0.5	0.5	0.5	0.4	0.5
16	0.4	0.4	0.4	0.4	0.6
17	0.5	0.5	0.5	0.5	0.4
18	0.5	0.4	0.3	0.4	0.3
19	0.5	0.5	0.5	0.5	0.5
20	0.5	0.5	0.4	0.3	0.5

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
21	0.5	0.5	0.5	0.5	0.6
22	0.5	0.5	0.5	0.4	0.5
23	0.5	0.5	0.5	0.5	0.5
24	0.5	0.5	0.5	0.5	0.5
25	0.5	0.5	0.4	0.3	0.7
26	0.6	0.6	0.5	0.5	0.6
27	0.5	0.5	0.5	0.4	0.5
28	0.5	0.5	0.5	0.5	0.5
29	0.6	0.5	0.4	0.5	0.5
30	0.6	0.5	0.5	0.5	0.5
31	0.6	0.5	0.5	0.5	0.6
32	0.7	0.7	0.6	0.6	0.6
33	0.5	0.5	0.6	0.5	0.5
34	0.5	0.5	0.6	0.5	0.5
35	0.6	0.5	0.4	0.5	0.5
36	0.5	0.5	0.5	0.5	0.5
37	0.5	0.5	0.5	0.5	0.5
38	0.5	0.5	0.5	0.5	0.5
39	0.5	0.6	0.5	0.5	0.6
40	0.5	0.5	0.4	0.3	0.5

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
41	0.4	0.5	0.4	0.5	0.4
42	0.5	0.4	0.5	0.5	0.4
43	0.4	0.5	0.5	0.5	0.5
44	0.5	0.5	0.5	0.4	0.5
45	0.3	0.4	0.5	0.4	0.3
46	0.6	0.7	0.6	0.7	0.7
47	0.6	0.5	0.6	0.5	0.6
48	0.5	0.6	0.6	0.6	0.7
49	0.6	0.7	0.7	0.6	0.7
50	0.6	0.6	0.6	0.5	0.4
51	0.6	0.5	0.5	0.5	0.5
52	0.5	0.5	0.5	0.5	0.5
53	0.6	0.6	0.5	0.6	0.7
54	0.5	0.5	0.5	0.6	0.5
55	0.5	0.5	0.5	0.6	0.6
56	0.6	0.6	0.5	0.5	0.5
57	0.5	0.5	0.5	0.5	0.4
58	0.5	0.5	0.5	0.5	0.6
59	0.5	0.5	0.5	0.5	0.5
60	0.7	0.7	0.5	0.5	0.7

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
61	0.7	0.5	0.5	0.5	0.5
62	0.5	0.5	0.5	0.5	0.5
63	0.4	0.3	0.3	0.3	0.4
64	0.5	0.5	0.5	0.5	0.5
65	0.5	0.5	0.5	0.5	0.5
66	0.5	0.5	0.5	0.5	0.5
67	0.5	0.5	0.5	0.5	0.5
68	0.6	0.6	0.6	0.4	0.6
69	0.5	0.5	0.5	0.5	0.5
70	0.4	0.5	0.5	0.4	0.4
71	0.5	0.5	0.4	0.4	0.5
72	0.3	0.3	0.3	0.3	0.5
73	0.5	0.4	0.4	0.3	0.4
74	0.5	0.5	0.5	0.5	0.4
75	0.5	0.3	0.4	0.2	0.4
76	0.5	0.4	0.4	0.4	0.4
77	0.2	0.2	0.3	0.2	0.4
78	0.5	0.5	0.5	0.5	0.5
79	0.5	0.5	0.5	0.5	0.5
80	0.5	0.6	0.6	0.5	0.5

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
81	0.5	0.5	0.4	0.5	0.4
82	0.5	0.5	0.5	0.3	0.3
83	0.5	0.5	0.5	0.3	0.5
84	0.5	0.4	0.4	0.3	0.2
85	0.5	0.5	0.5	0.5	0.5
86	0.5	0.5	0.5	0.5	0.5
87	0.4	0.4	0.3	0.2	0.4
88	0.6	0.5	0.4	0.3	0.6
89	0.5	0.5	0.5	0.4	0.3
90	0.5	0.5	0.5	0.4	0.5
91	0.5	0.5	0.5	0.5	0.5
92	0.6	0.5	0.5	0.5	0.6
93	0.5	0.5	0.5	0.6	0.5
94	0.4	0.4	0.4	0.4	0.4
95	0.5	0.5	0.5	0.5	0.5
96	0.5	0.5	0.5	0.5	0.5
97	0.6	0.6	0.5	0.5	0.6
98	0.4	0.4	0.4	0.4	0.3
99	0.5	0.5	0.5	0.5	0.6
100	0.4	0.5	0.5	0.4	0.5

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
101	0.5	0.5	0.5	0.5	0.5
102	0.5	0.5	0.5	0.4	0.5
103	0.6	0.7	0.6	0.7	0.5
104	0.5	0.6	0.7	0.5	0.6
105	0.5	0.5	0.5	0.5	0.3
106	0.5	0.5	0.5	0.7	0.5
107	0.5	0.5	0.5	0.5	0.5
108	0.4	0.5	0.5	0.3	0.3
109	0.5	0.6	0.7	0.6	0.7
110	0.5	0.4	0.4	0.5	0.5
111	0.5	0.6	0.6	0.5	0.5
112	0.5	0.5	0.6	0.6	0.4
113	0.5	0.6	0.6	0.5	0.6
114	0.5	0.5	0.7	0.6	0.6
115	0.5	0.5	0.5	0.5	0.6
116	0.6	0.6	0.6	0.6	0.6
117	0.5	0.5	0.6	0.5	0.6
118	0.5	0.5	0.5	0.5	0.5
119	0.5	0.5	0.6	0.6	0.5
120	0.5	0.6	0.6	0.5	0.5

Appendix Two

Data Collection Table

Veneer Thickness
ARI (Bracket)
ARI (Tooth)
Veneer Damage
Temperature Increase
Treatment Group

Data Collection Table

Sample #	Exposed Dentin	Veneer Thickness	ARI Bracket	ARI Tooth	Veneer Damage	Temp. Increase	Treatment Group
1	No	0.5 mm	1* 34.77	2 66%BR 33%C	-	-	B
2	No	0.4 mm	2 71.44	3 15%BR 85%VR	Y reversible	-	D
3	No	0.5 mm	-	-	-	-	Control
4	No	0.6 mm	2 89.52	4* 5%BR 95%VR	-	3.1°C	ETD (M)
5	No	0.3 mm	1 23.02	3 15%VR 85%BR	-	4.4°C	ETD (C)
6	No	0.6 mm	2* 8.42	2 85%BR 10%Co 5%VR	-	-	B
7	No	0.5 mm	2 33.79	2 35%BR 10%VR 55%Co	-	-	B
8	No	0.5 mm	2 83.53	3 75%VR 25%BR	-	5.7°C	ETD (C)
9	No	0.3 mm	3 100.00	3* 80%VR 20%Co	-	3.5°C	ETD (M)
10	No	0.3 mm	3 100.00	4 95%VR 5%Co	-	-	D
11	No	0.4 mm	2 66.35	2 60%Co 35%BR 5%VR	-	2.7°C	ETD (C)
12	No	0.3 mm	-	-	-	-	Control
13	No	0.5 mm	1* 2.40	1 98%BR 2%VR	-	-	B
14	No	0.5 mm	2 82.00	3* 10%BR 10%Co 80%VR	-	9.1°C	ETD (M)
15	No	0.5 mm	1* 18.69	2 50%BR 40%Co 10%VR	-	-	B
16	No	0.4 mm	2 94.95	3 15%Co 80%VR 5%BR	-	3.8°C	ETD (C)
17	No	0.5 mm	2 87.47	3 25%Co 75%VR	-	-	D
18	No	0.4 mm	1 11.35	2 5%VR 95%BR	-	1.9°C	ETD (C)
19	No	0.5 mm	-	-	-	-	Control
20	No	0.5 mm	2 86.90	4* 95%VR 5%Co	-	7.6°C	ETD (M)

Sample #	Exposed Dentin	Veneer Thickness	ARI Bracket	ARI Tooth	Veneer Damage	Temp. Increase	Treatment Group
21	No	0.5 mm	1* 43.67	2 50%BR 50%Co	-	-	D
22	No	0.5 mm	1* 35.32	1 75%BR 20%Co 5%VR	Y irreversible	-	B
23	No	0.5 mm	-	-	-	-	Control
24	No	0.5 mm	1* 26.51	1 30%Co 65%BR 5%VR	-	-	B
25	No	0.5 mm	1* 13.69	2 50%BR 40%Co 10%VR	Y reversible	-	D
26	No	0.6 mm	-	-	-	-	Control
27	No	0.5 mm	1 19.97	3 60%BR 15%Co 25%VR	-	8.8°C	ETD (M)
28	No	0.5 mm	1* 31.12	1 33%BR 66%Co	Y irreversible	-	B
29	No	0.5 mm	1 4.38	2 5%VR 95%BR	-	2.5°C	ETD (C)
30	No	0.5 mm	-	-	-	-	Control
31	No	0.5 mm	1 36.15	1 33%Co 66%BR	-	2.5°C	ETD (C)
32	No	0.7 mm	2 97.72	4 5%Co 95%VR	-	4.9°C	ETD (C)
33	No	0.5 mm	-	-	-	-	Control
34	No	0.5 mm	1* 15.22	1 50%BR 50%Co	-	-	D
35	No	0.5 mm	2* 75.79	2 70%BR 30%VR	Y reversible	-	D
36	No	0.5 mm	2 88.39	3* 70%VR 15%Co 15%BR	-	6.4°C	ETD (M)
37	No	0.5 mm	-	-	-	-	Control
38	No	0.5 mm	2* 92.52	2 50%BR 50%Co	-	-	D
39	No	0.5 mm	3 99.41	5* 100%VR	-	2.9°C	ETD (M)
40	No	0.5 mm	-	-	-	-	Control

Sample #	Exposed Dentin	Veneer Thickness	ARI Bracket	ARI Tooth	Veneer Damage	Temp. Increase	Treatment Group
41	No	0.4 mm	1* 13.77	1 40%BR 60%Co	Y irreversible	-	B
42	No	0.5 mm	1* 5.19	1 90%BR 10%Co	-	-	D
43	No	0.5 mm	1* 11.27	2 70%BR 15%VR 15%Co	-	-	B
44	No	0.5 mm	3 98.30	4* 5%Co 95%VR	-	3.0°C	ETD (M)
45	No	0.4 mm	1* 11.55	2 50%BR 40%Co 10%VR	-	-	B
46	No	0.6 mm	2 70.35	2 20%VR 40%Co 40%BR	-	5.5°C	ETD (C)
47	No	0.6 mm	-	-	-	-	Control
48	No	0.6 mm	1 33.31	1 50%Co 50%BR	-	1.2°C	ETD (C)
49	No	0.7 mm	4	5*	Y - total	-	D
50	No	0.6 mm	3 100.00	3* 15%Co 85%VR	-	4.5°C	ETD (M)
51	No	0.5 mm	1* 12.28	1 85%BR 15%Co	-	-	B
52	No	0.5 mm	-	-	-	-	Control
53	No	0.6 mm	3 98.44	5* 95%VR 5%Co	-	4.9°C	ETD (M)
54	No	0.5 mm	1 32.76	1 66%BR 33%Co	-	3.7°C	ETD (C)
55	No	0.5 mm	1* 19.06	3 50%BR 25%Co 25%VR	-	-	D
56	No	0.6 mm	1 4.36	2 5%Co 95%BR	-	3.5°C	ETD (C)
57	No	0.5 mm	-	-	-	-	Control
58	No	0.5 mm	2 20.62	2 10%BR 80%Co 10%VR	Y reversible	-	B
59	No	0.5 mm	-	-	-	-	Control
60	No	0.6 mm	2 91.37	4* 5%BR 95%VR	Y reversible	5.4°C	ETD (M)

Sample #	Exposed Dentin	Veneer Thickness	ARI Bracket	ARI Tooth	Veneer Damage	Temp. Increase	Treatment Group
61	No	0.6 mm	1* 22.54	1 80%BR 20%Co	-	-	D
62	No	0.5 mm	3 93.38	4* 10%Co 90%VR	-	4.8°C	ETD (M)
63	No	0.3 mm	1 26.15	2* 80%BR 10%Co 10%VR	-	2.5°C	ETD (C)
64	No	0.5 mm	2 84.71	4 95%VR 5%BR	-	9.5°C	ETD (M)
65	No	0.5 mm	1* 25.52	1 75%BR 25%Co	-	-	B
66	No	0.5 mm	2 66.77	3 66%VR 33%BR	-	3.8°C	ETD (C)
67	No	0.5 mm	-	-	-	-	Control
68	No	0.6 mm	2 60.07	3 50%BR 30%VR 20%Co	Y reversible	-	D
69	No	0.5 mm	-	-	-	-	Control
70	No	0.5 mm	1 45.86	1 50%BR 50%Co	-	-	B
71	No	0.5 mm	2 44.69	3 40%BR 40%Co 20%VR	-	-	D
72	No	0.3 mm	1* 24.00	1 80%BR 20%Co	Y reversible	13.5°C	ETD (M)
73	No	0.4 mm	1* 21.50	1 85%BR 15%Co	-	-	B
74	No	0.5 mm	1 12.62	2 10%Co 90%BR	-	5.0°C	ETD (C)
75	No	0.4 mm	-	-	-	-	Control
76	No	0.4 mm	2 58.50	3* 25%BR 25%Co 50%VR	-	5.0°C	ETD (M)
77	No	0.2 mm	2 78.53	3 10%BR 90%VR	-	5.2°C	ETD (C)
78	No	0.5 mm	1* 20.41	3 50%BR 25%VR 25%Co	-	-	D
79	No	0.5 mm	-	-	-	-	Control
80	No	0.6 mm	1* 18.98	2 60%BR 30%Co 10%VR	-	-	D

Sample #	Exposed Dentin	Veneer Thickness	ARI Bracket	ARI Tooth	Veneer Damage	Temp. Increase	Treatment Group
81	No	0.5 mm	2 87.53	3 5%BR 35%Co 60%VR	-	-	B
82	No	0.5 mm	-	-	-	-	Control
83	No	0.5 mm	2 79.52	1 10%BR 90%Co	-	2.3°C	ETD (C)
84	No	0.4 mm	1* 31.70	1 75%BR 25%Co	-	-	B
85	No	0.5 mm	1* 17.80	1 75%BR 25%Co	-	-	B
86	No	0.5 mm	1* 22.36	2 50%BR 40%Co 10%VR	Y reversible	-	D
87	No	0.4 mm	-	-	-	-	Control
88	No	0.5 mm	2 85.42	3* 33%Co 66%VR	-	3.2°C	ETD (M)
89	No	0.5 mm	1 9.15	1 100%BR	-	2.7°C	ETD (C)
90	No	0.5 mm	1* 33.60	1 50%BR 35%Co 15%VR	-	-	B
91	No	0.5 mm	2 63.92	3 50%BR 45%VR 5%Co	Y reversible	-	D
92	No	0.5 mm	1* 9.76	1 10%VR 90%BR	-	7.4°C	ETD (M)
93	No	0.5 mm	1* 35.63	3 70%BR 30%VR	-	-	D
94	No	0.4 mm	-	-	-	-	Control
95	No	0.5 mm	-	-	-	-	Control
96	No	0.5 mm	1* 21.32	1 75%BR 20%Co 5%VR	-	-	B
97	No	0.6 mm	2 60.44	3 25%Co 75%VR	-	3.2°C	ETD (C)
98	No	0.4 mm	2 75.78	3* 10%BR 90%VR	Y reversible	6.1°C	ETD (M)
99	No	0.5 mm	1 11.76	1 10%Co 90%BR	-	3.3°C	ETD (C)
100	No	0.5 mm	2 91.37	3 15%BR 85%VR	Y reversible	-	B

Sample #	Exposed Dentin	Veneer Thickness	ARI Bracket	ARI Tooth	Veneer Damage	Temp. Incr.	Treatment Group
101	No	0.5 mm	3 98.94	3 25%Co 75%VR	-	4.7°C	ETD (C)
102	No	0.5 mm	3 99.65	5* 100%VR	-	1.9°C	ETD (M)
103	No	0.6 mm	3 98.53	4* 100%VR	-	17.2°C	ETD (M)
104	No	0.6 mm	-	-	-	-	Control
105	No	0.5 mm	1* 7.32	2 90%BR 10%VR	-	-	B
106	No	0.5 mm	2 71.24	2 40%BR 40%Co 20%VR	Y reversible	-	D
107	No	0.5 mm	2 93.99	3 10%BR 20%Co 70%VR	-	3.9°C	ETD (C)
108	No	0.5 mm	1* 6.58	1 90%BR 10%Co	-	-	B
109	No	0.6 mm	2 63.22	3 33%VR 66%BR	-	3.7°C	ETD (C)
110	No	0.4 mm	1* 15.64	1 66%BR 33%Co	-	-	D
111	No	0.6 mm	1 42.58	3* 10%BR 50%Co 40%VR	-	13.6°C	ETD (M)
112	No	0.5 mm	2 50.71	2 33%BR 33%VR 33%Co	Y reversible	-	D
113	No	0.6 mm	-	-	-	-	Control
114	No	0.6 mm	1 6.29	2 5%VR 95%BR	-	2.5°C	ETD (C)
115	No	0.5 mm	3 97.72	4* 100%VR	-	4.4°C	ETD (M)
116	No	0.6 mm	1* 25.18	1 50%BR 50%Co	-	-	D
117	No	0.5 mm	1* 39.38	1 50%BR 50%Co	-	-	D
118	No	0.5 mm	3 98.87	4* 100%VR	-	6.1°C	ETD (M)
119	No	0.5 mm	-	-	-	-	Control
120	No	0.6 mm	3 97.80	4* 100%VR	-	5.2°C	ETD (M)

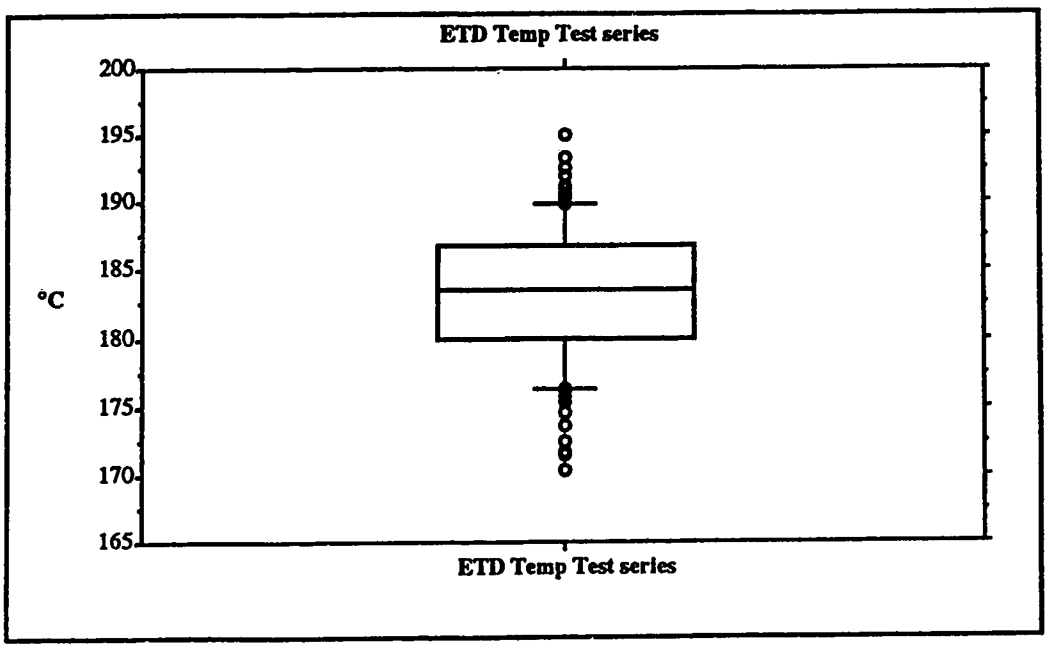
Appendix Three

Electrothermal Debonder Temperature

1.	192.5	36.	185.5	71.	184.4	106.	183.2
2.	179.0	37.	179.8	72.	179.3	107.	188.2
3.	187.9	38.	172.4	73.	184.3	108.	181.5
4.	183.1	39.	183.2	74.	186.2	109.	187.6
5.	181.5	40.	177.5	75.	185.1	110.	177.6
6.	191.2	41.	191.0	76.	184.7	111.	178.5
7.	188.4	42.	188.8	77.	175.8	112.	183.2
8.	171.7	43.	187.6	78.	181.4	113.	186.1
9.	181.1	44.	188.5	79.	174.5	114.	186.6
10.	170.3	45.	178.0	80.	181.7	115.	195.0
11.	187.7	46.	178.8	81.	177.9	116.	184.4
12.	187.5	47.	181.8	82.	179.8		
13.	180.7	48.	183.1	83.	180.4		
14.	173.6	49.	186.9	84.	183.4		
15.	187.0	50.	180.0	85.	187.0		
16.	190.4	51.	179.1	86.	178.4		
17.	185.1	52.	185.2	87.	178.4		
18.	185.4	53.	184.9	88.	177.7		
19.	186.0	54.	184.4	89.	176.1		
20.	187.7	55.	179.0	90.	180.4		
21.	185.7	56.	183.0	91.	188.8		
22.	193.3	57.	190.2	92.	192.0		
23.	175.4	58.	180.1	93.	183.8		
24.	174.6	59.	191.2	94.	176.2		
25.	185.0	60.	190.7	95.	195.0		
26.	185.0	61.	182.1	96.	175.3		
27.	183.3	62.	176.4	97.	185.5		
28.	184.4	63.	171.5	98.	183.6		
29.	180.7	64.	187.6	99.	180.2		
30.	180.4	65.	184.2	100.	79.8		
31.	180.1	66.	181.7	101.	181.5		
32.	184.4	67.	185.5	102.	177.2		
33.	186.9	68.	185.5	103.	185.9		
34.	189.9	69.	178.3	104.	185.3		
35.	189.2	70.	183.6	105.	184.6		

Test #1 (Battery #2 Tip #1 @ 5 sec) 116 trials Average = 21246.7/116 = 183.2°C

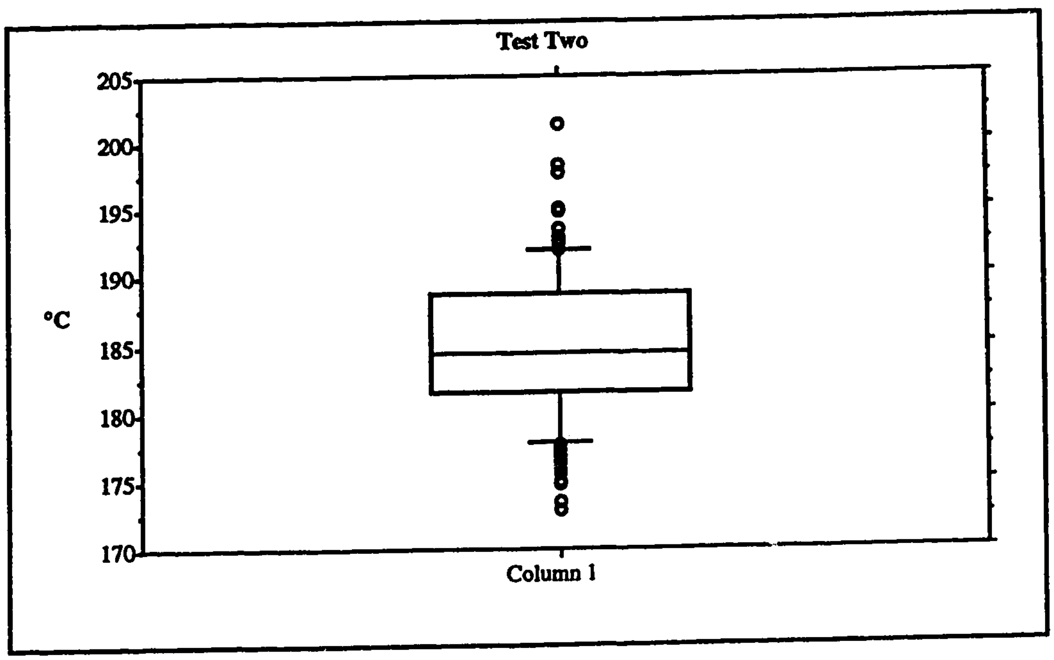
X1: ETD Temp Test series					
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
183.1612	5.1415	.4774	26.4346	2.8071	116
Minimum:	Maximum:	Range:	Sum:	Sum of Sqr.:	# Missing:
170.3	195	24.7	21246.7	3894611.19	0



1. 180.4	36. 176.4	71. 181.2	106. 179.2
2. 191.6	37. 182.4	72. 180.7	107. 188.0
3. 192.9	38. 189.3	73. 175.6	108. 188.7
4. 186.8	39. 189.1	74. 182.6	109. 178.9
5. 189.6	40. 174.8	75. 183.0	110. 184.6
6. 192.0	41. 192.8	76. 177.8	111. 188.7
7. 184.4	42. 195.1	77. 185.6	112. 179.6
8. 183.9	43. 187.5	78. 172.8	113. 189.3
9. 183.7	44. 192.4	79. 180.2	114. 193.6
10. 182.4	45. 198.4	80. 184.2	115. 188.3
11. 185.9	46. 181.9	81. 182.1	116. 186.4
12. 184.2	47. 181.9	82. 176.0	117. 186.0
13. 186.0	48. 190.1	83. 184.7	118. 182.1
14. 190.4	49. 185.9	84. 184.3	119. 187.4
15. 193.6	50. 186.8	85. 183.9	120. 187.0
16. 194.9	51. 183.2	86. 188.1	121. 188.7
17. 182.7	52. 183.2	87. 173.4	122. 183.6
18. 186.8	53. 189.8	88. 187.5	123. 188.9
19. 188.9	54. 185.8	89. 175.5	124. 191.9
20. 190.4	55. 186.6	90. 182.5	125. 175.0
21. 184.1	56. 188.1	91. 180.6	126. 180.3
22. 184.3	57. 183.7	92. 185.9	127. 178.7
23. 187.6	58. 197.7	93. 178.1	128. 182.4
24. 201.3	59. 184.6	94. 182.4	129. 187.2
25. 178.7	60. 188.2	95. 184.0	130. 179.9
26. 185.1	61. 179.1	96. 182.8	131. 179.2
27. 191.9	62. 186.1	97. 180.3	132. 182.0
28. 189.8	63. 190.5	98. 176.9	133. 186.8
29. 179.5	64. 181.3	99. 192.4	134. 180.1
30. 189.1	65. 181.3	100. 181.8	135. 182.8
31. 189.3	66. 178.0	101. 182.9	
32. 191.4	67. 177.3	102. 184.4	
33. 190.6	68. 181.8	103. 176.5	
34. 192.5	69. 175.9	104. 177.6	
35. 190.3	70. 178.9	105. 187.0	

Test #2 (Battery #1 Tip #1 @ 5 sec) 135 trials **Average = 24953.5 / 135 = 184.8**

X1: Column 1					
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
184.8407	5.441	.4683	29.6041	2.9436	135
Minimum:	Maximum:	Range:	Sum:	Sum of Sqr.:	# Missing:
172.8	201.3	28.5	24953.5	4616390.37	0



1. 217.6
2. 218.0
3. 212.8
4. 211.8
5. 215.2

6. 207.2
7. 216.1
8. 215.5
9. 221.1
10. 214.9

11. 217.7
12. 217.2
13. 220.5
14. 221.2
15. 215.6

16. 214.5
17. 221.5
18. 220.5
19. 220.3
20. 222.2

21. 219.1
22. 221.0
23. 220.6
24. 223.2
25. 218.9

26. 217.7
27. 229.8
28. 213.3
29. 217.8
30. 220.8

31. 222.9
32. 218.3
33. 217.8
34. 217.2
35. 223.6

36. 206.6
37. 221.6
38. 220.0
39. 219.8
40. 219.8

41. 214.2
42. 218.4
43. 217.2
44. 209.9
45. 221.2

46. 211.5
47. 214.0
48. 212.8
49. 215.6
50. 220.9

51. 220.7
52. 219.0
53. 218.2
54. 216.8
55. 221.0

56. 216.6
57. 219.7
58. 220.0
59. 217.0
60. 219.6

61. 222.4
62. 218.8
63. 222.0
64. 223.7
65. 227.7

66. 212.3
67. 215.9
68. 213.0
69. 214.9
70. 216.6

71. 214.4
72. 209.3
73. 215.9
74. 213.6
75. 213.6

76. 212.8
77. 216.8
78. 221.7
79. 216.4
80. 212.2

81. 217.3
82. 218.6
83. 219.6
84. 215.5
85. 204.9

86. 202.6
87. 208.8
88. 210.1
89. 208.8
90. 207.5

91. 209.4
92. 210.0
93. 205.8
94. 205.2
95. 208.9

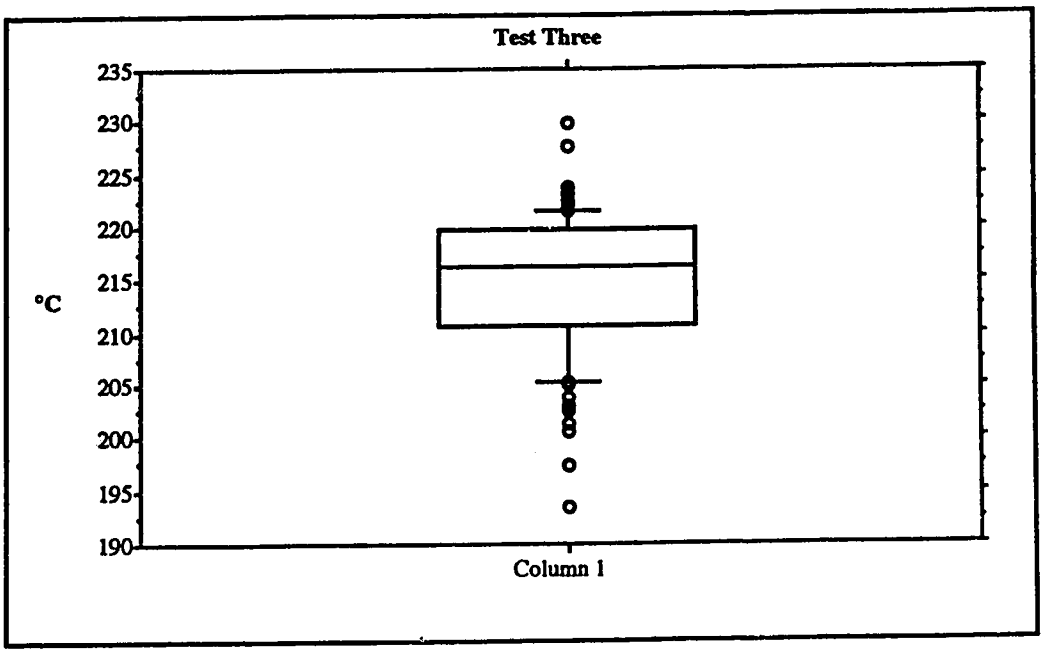
96. 201.4
97. 202.8
98. 208.8
99. 203.8
100. 193.4

101. 208.8
102. 203.1
103. 200.6
104. 208.8
105. 208.0

106. 197.3
107. 202.7

Test #3 (Battery #2 Tip #1 @ 10 sec)   107 trials   Average = 214.9

X_1: Column 1					
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
214.8879	6.5257	.6309	42.5849	3.0368	107
Minimum:	Maximum:	Range:	Sum:	Sum of Sqr.:	# Missing:
193.4	229.8	36.4	22993	4945430.34	0



1. 210.6
2. 220.4
3. 218.0
4. 223.4
5. 216.9

6. 214.8
7. 212.3
8. 214.0
9. 216.8
10. 222.6

11. 214.2
12. 215.3
13. 217.5
14. 219.0
15. 216.8

16. 219.3
17. 212.3
18. 217.2
19. 220.5
20. 208.9

21. 209.7
22. 214.2
23. 210.7
24. 216.0
25. 207.3

26. 215.6
27. 215.0
28. 213.8
29. 208.9
30. 209.4

31. 217.8
32. 212.0
33. 212.3
34. 213.5
35. 209.1

36. 210.8
37. 210.7
38. 203.7
39. 213.1
40. 211.8

41. 210.9
42. 213.7
43. 205.5
44. 215.0
45. 206.4

46. 209.5
47. 217.4
48. 219.3
49. 216.4
50. 218.8

51. 215.6
52. 213.5
53. 219.9
54. 222.2
55. 216.5

56. 209.8
57. 213.2
58. 211.9
59. 210.3
60. 214.5

61. 206.5
62. 213.9
63. 205.2
64. 214.1
65. 214.8

66. 213.7
67. 214.8
68. 209.3
69. 214.2
70. 213.0

71. 203.0
72. 203.7
73. 208.7
74. 207.3
75. 210.4

76. 209.6
77. 207.1
78. 208.8
79. 204.0
80. 208.8

81. 210.6
82. 199.4
83. 208.8
84. 213.6
85. 203.0

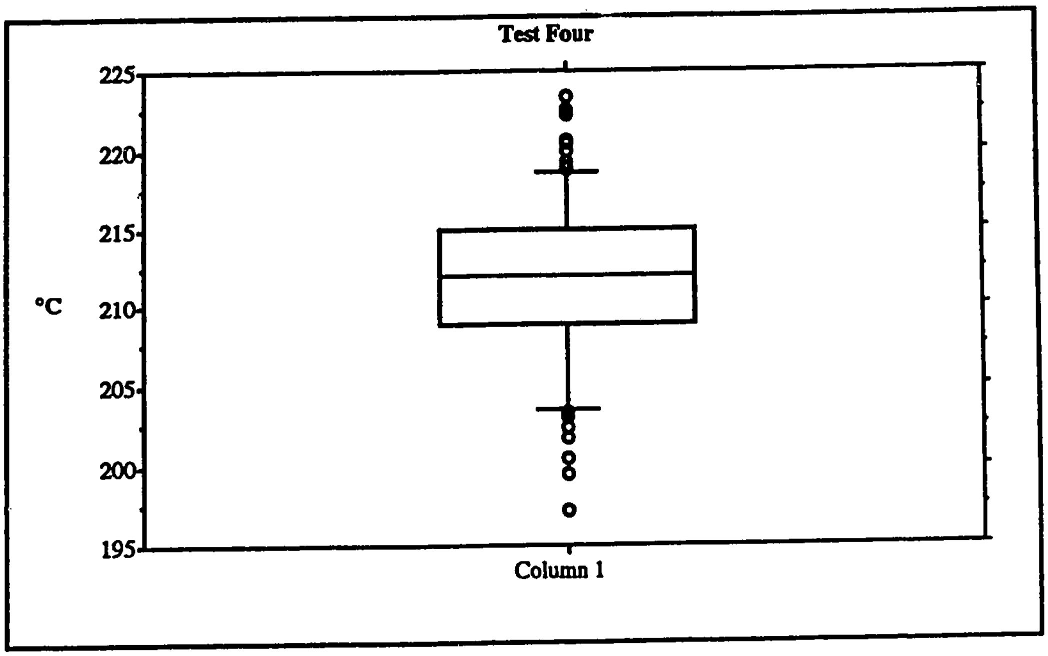
86. 205.9
87. 200.4
88. 201.7
89. 203.4
90. 197.1

91. 204.7
92. 208.9
93. 203.8
94. 209.2
95. 202.4

96. 202.3
97. 201.8

Test #4 (Battery #1 Tip #1 @ 10 sec) 97 trials Average = 20514.4 / 97 = 211.5

X1: Column 1					
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
211.4887	5.5946	.568	31.2996	2.6453	97
Minimum:	Maximum:	Range:	Sum:	Sum of Sqr.:	# Missing:
197.1	223.4	26.3	20514.4	4341567.72	0



Appendix Four

Statistics

ANOVA
T-tests
Correlation Coefficients

For Treatment Group "B"
ARIBRACK ARI percentage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	2.4	1	4.2	4.2	4.2
	6.6	1	4.2	4.2	8.3
	7.3	1	4.2	4.2	12.5
	8.4	1	4.2	4.2	16.7
	11.3	1	4.2	4.2	20.8
	11.6	1	4.2	4.2	25.0
	12.3	1	4.2	4.2	29.2
	13.8	1	4.2	4.2	33.3
	17.8	1	4.2	4.2	37.5
	18.7	1	4.2	4.2	41.7
	20.6	1	4.2	4.2	45.8
	21.3	1	4.2	4.2	50.0
	21.5	1	4.2	4.2	54.2
	25.5	1	4.2	4.2	58.3
	26.5	1	4.2	4.2	62.5
	31.1	1	4.2	4.2	66.7
	31.7	1	4.2	4.2	70.8
	33.6	1	4.2	4.2	75.0
	33.8	1	4.2	4.2	79.2
	34.8	1	4.2	4.2	83.3
	35.3	1	4.2	4.2	87.5
	45.9	1	4.2	4.2	91.7
	87.5	1	4.2	4.2	95.8
	91.4	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	27.109	Std err	4.527	Median	21.410
Mode	2.400	Std dev	22.178	Variance	491.868
Kurtosis	3.931	S E Kurt	.918	Skewness	1.917
S E Skew	.472	Range	88.970	Minimum	2.400
Maximum	91.370	Sum	650.610		

Valid cases 24 Missing cases 0

For Treatment Group "B"
ARISCORE Bracket score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
< 1/2 adhesive left	1.0	19	79.2	79.2	79.2
> 1/2 adhesive left	2.0	5	20.8	20.8	100.0
	Total	24	100.0	100.0	

Mean	1.208	Std err	.085	Median	1.000
Mode	1.000	Std dev	.415	Variance	.172
Kurtosis	.377	S E Kurt	.918	Skewness	1.534
S E Skew	.472	Range	1.000	Minimum	1.000
Maximum	2.000	Sum	29.000		

Valid cases 24 Missing cases 0

- -

VENSCORE Veneer score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
All of the composite	1.0	14	58.3	58.3	58.3
Greater than 90% com	2.0	8	33.3	33.3	91.7
>10% but <90% compos	3.0	2	8.3	8.3	100.0
	Total	24	100.0	100.0	

Mean	1.500	Std err	.135	Median	1.000
Mode	1.000	Std dev	.659	Variance	.435
Kurtosis	.000	S E Kurt	.918	Skewness	.993
S E Skew	.472	Range	2.000	Minimum	1.000
Maximum	3.000	Sum	36.000		

Valid cases 24 Missing cases 0

- -

VENTHIC Veneer thickness

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.4	4	16.7	16.7	16.7
	.5	19	79.2	79.2	95.8
	.6	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	.488	Std err	.009	Median	.500
Mode	.500	Std dev	.045	Variance	.002
Kurtosis	2.082	S E Kurt	.918	Skewness	-.641
S E Skew	.472	Range	.200	Minimum	.400
Maximum	.600	Sum	11.700		

Valid cases 24 Missing cases 0

For Treatment Group "B"
TOOTHBR ARI Tooth %BR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	5.0	1	4.2	4.2	4.2
	10.0	1	4.2	4.2	8.3
	15.0	1	4.2	4.2	12.5
	33.0	1	4.2	4.2	16.7
	35.0	1	4.2	4.2	20.8
	40.0	1	4.2	4.2	25.0
	50.0	4	16.7	16.7	41.7
	65.0	1	4.2	4.2	45.8
	66.0	1	4.2	4.2	50.0
	70.0	1	4.2	4.2	54.2
	75.0	5	20.8	20.8	75.0
	85.0	3	12.5	12.5	87.5
	90.0	2	8.3	8.3	95.8
	98.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	60.292	Std err	5.402	Median	68.000
Mode	75.000	Std dev	26.463	Variance	700.303
Kurtosis	-.433	S E Kurt	.918	Skewness	-.691
S E Skew	.472	Range	93.000	Minimum	5.000
Maximum	98.000	Sum	1447.000		

Valid cases 24 Missing cases 0

- -

TOOTHCO ARI Tooth % CO

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	3	12.5	12.5	12.5
	10.0	2	8.3	8.3	20.8
	15.0	3	12.5	12.5	33.3
	20.0	2	8.3	8.3	41.7
	25.0	3	12.5	12.5	54.2
	30.0	1	4.2	4.2	58.3
	33.0	1	4.2	4.2	62.5
	35.0	2	8.3	8.3	70.8
	40.0	2	8.3	8.3	79.2
	50.0	1	4.2	4.2	83.3
	55.0	1	4.2	4.2	87.5
	60.0	1	4.2	4.2	91.7
	65.0	1	4.2	4.2	95.8
	80.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	29.333	Std err	4.345	Median	25.000
Mode	.000	Std dev	21.284	Variance	453.014
Kurtosis	023	S E Kurt	.918	Skewness	.669
S E Skew	.472	Range	80.000	Minimum	.000
Maximum	80.000	Sum	704.000		

Valid cases 24 Missing cases 0

For Treatment Group "B"

TOOTHVR ARI Tooth # VR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	10	41.7	41.7	41.7
	2.0	1	4.2	4.2	45.8
	5.0	4	16.7	16.7	62.5
	10.0	5	20.8	20.8	83.3
	15.0	2	8.3	8.3	91.7
	60.0	1	4.2	4.2	95.8
	85.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	10.292	Std err	4.113	Median	5.000
Mode	.000	Std dev	20.148	Variance	405.955
Kurtosis	9.372	S E Kurt	.918	Skewness	3.061
S E Skew	.472	Range	85.000	Minimum	.000
Maximum	85.000	Sum	247.000		

Valid cases 24 Missing cases 0

- -

VENDAM Veneer Damage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1.0	5	20.8	20.8	20.8
	2.0	19	79.2	79.2	100.0
	Total	24	100.0	100.0	

Mean	1.792	Std err	.085	Median	2.000
Mode	2.000	Std dev	.415	Variance	.172
Kurtosis	.377	S E Kurt	.918	Skewness	-1.534
S E Skew	.472	Range	1.000	Minimum	1.000
Maximum	2.000	Sum	43.000		

Valid cases 24 Missing cases 0

For Treatment Group "D"
ARIBRACK ARI percentage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	5.2	1	4.3	4.3	4.3
	13.7	1	4.3	4.3	8.7
	15.2	1	4.3	4.3	13.0
	15.6	1	4.3	4.3	17.4
	19.0	1	4.3	4.3	21.7
	19.1	1	4.3	4.3	26.1
	20.4	1	4.3	4.3	30.4
	22.4	1	4.3	4.3	34.8
	22.5	1	4.3	4.3	39.1
	25.2	1	4.3	4.3	43.5
	35.6	1	4.3	4.3	47.8
	39.4	1	4.3	4.3	52.2
	43.7	1	4.3	4.3	56.5
	44.7	1	4.3	4.3	60.9
	50.7	1	4.3	4.3	65.2
	60.1	1	4.3	4.3	69.6
	63.9	1	4.3	4.3	73.9
	71.2	1	4.3	4.3	78.3
	71.4	1	4.3	4.3	82.6
	75.8	1	4.3	4.3	87.0
	87.5	1	4.3	4.3	91.3
	92.5	1	4.3	4.3	95.7
	100.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	44.122	Std err	5.935	Median	39.380
Mode	5.190	Std dev	28.462	Variance	810.097
Kurtosis	-.973	S E Kurt	.935	Skewness	.532
S E Skew	.481	Range	94.810	Minimum	5.190
Maximum	100.000	Sum	1014.800		

Valid cases 23 Missing cases 0

For Treatment Group "D"

ARISCORE Bracket score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
< 1/2 adhesive left	1.0	13	56.5	56.5	56.5
> 1/2 adhesive left	2.0	9	39.1	39.1	95.7
All base covered by	3.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	1.478	Std err	.124	Median	1.000
Mode	1.000	Std dev	.593	Variance	.352
Kurtosis	-.218	S E Kurt	.935	Skewness	.806
S E Skew	.481	Range	2.000	Minimum	1.000
Maximum	3.000	Sum	34.000		

Valid cases 23 Missing cases 0

- -

VENSCORE Veneer score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
All of the composite	1.0	6	26.1	26.1	26.1
Greater than 90% com	2.0	8	34.8	34.8	60.9
>10% but <90% compos	3.0	8	34.8	34.8	95.7
Less than 10% compos	4.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	2.174	Std err	.185	Median	2.000
Mode	2.000	Std dev	.887	Variance	.787
Kurtosis	-.923	S E Kurt	.935	Skewness	.061
S E Skew	.481	Range	3.000	Minimum	1.000
Maximum	4.000	Sum	50.000		

Valid cases 23 Missing cases 0

For Treatment Group "D"

VENTHIC Veneer thickness

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.3	1	4.3	4.3	4.3
	.4	2	8.7	8.7	13.0
	.5	16	69.6	69.6	82.6
	.6	4	17.4	17.4	100.0
	Total	23	100.0	100.0	

Mean	.500	Std err	.014	Median	.500
Mode	.500	Std dev	.067	Variance	.005
Kurtosis	2.904	S E Kurt	.935	Skewness	-.975
S E Skew	.481	Range	.300	Minimum	.300
Maximum	.600	Sum	11.500		

Valid cases 23 Missing cases 0

- -

TOOTHBR ARI Tooth SBR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	2	8.7	8.7	8.7
	15.0	1	4.3	4.3	13.0
	33.0	1	4.3	4.3	17.4
	40.0	2	8.7	8.7	26.1
	50.0	11	47.8	47.8	73.9
	60.0	1	4.3	4.3	78.3
	66.0	1	4.3	4.3	82.6
	70.0	2	8.7	8.7	91.3
	80.0	1	4.3	4.3	95.7
	90.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	48.435	Std err	4.515	Median	50.000
Mode	50.000	Std dev	21.652	Variance	468.802
Kurtosis	1.122	S E Kurt	.935	Skewness	-.683
S E Skew	.481	Range	90.000	Minimum	000
Maximum	90.000	Sum	1114.000		

Valid cases 23 Missing cases 0

For Treatment Group "D"

TOOTHCO AAI Tooth # CO

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	3	13.0	13.0	13.0
	5.0	2	8.7	8.7	21.7
	10.0	1	4.3	4.3	26.1
	20.0	2	8.7	8.7	34.8
	25.0	3	13.0	13.0	47.8
	30.0	1	4.3	4.3	52.2
	33.0	2	8.7	8.7	60.9
	40.0	4	17.4	17.4	78.3
	50.0	5	21.7	21.7	100.0
	Total	23	100.0	100.0	

Mean	27.870	Std err	3.703	Median	30.000
Mode	50.000	Std dev	17.750	Variance	315.391
Kurtosis	-1.203	S E Kurt	.935	Skewness	-.302
S E Skew	.481	Range	50.000	Minimum	.000
Maximum	50.000	Sum	641.000		

Valid cases 23 Missing cases 0

- -

TOOTHUR AAI Tooth # UR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	7	30.4	30.4	30.4
	2.0	1	4.3	4.3	34.8
	10.0	3	13.0	13.0	47.8
	20.0	2	8.7	8.7	56.5
	25.0	2	8.7	8.7	65.2
	30.0	3	13.0	13.0	78.3
	33.0	1	4.3	4.3	82.6
	45.0	1	4.3	4.3	87.0
	75.0	1	4.3	4.3	91.3
	85.0	1	4.3	4.3	95.7
	95.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	23.696	Std err	5.818	Median	20.000
Mode	.000	Std dev	27.903	Variance	778.585
Kurtosis	1.436	S E Kurt	.935	Skewness	1.439
S E Skew	.481	Range	95.000	Minimum	.000
Maximum	95.000	Sum	545.000		

Valid cases 23 Missing cases 0

For Treatment Group "D"
VENDAM Veneer Damage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1.0	8	34.8	34.8	34.8
	2.0	15	65.2	65.2	100.0
	Total	23	100.0	100.0	

Mean	1.652	Std err	.102	Median	2.000
Mode	2.000	Std dev	.487	Variance	.237
Kurtosis	-1.687	S E Kurt	.935	Skewness	-.684
S E Skew	.481	Range	1.000	Minimum	1.000
Maximum	2.000	Sum	38.000		

Valid cases 23 Missing cases 0

For Treatment Group "ETD(M)"
ARIBRACK ARI percentage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	9.8	1	4.2	4.2	4.2
	20.0	1	4.2	4.2	8.3
	24.0	1	4.2	4.2	12.5
	42.6	1	4.2	4.2	16.7
	56.5	1	4.2	4.2	20.8
	75.8	1	4.2	4.2	25.0
	82.0	1	4.2	4.2	29.2
	84.7	1	4.2	4.2	33.3
	85.4	1	4.2	4.2	37.5
	86.9	1	4.2	4.2	41.7
	88.4	1	4.2	4.2	45.8
	89.5	1	4.2	4.2	50.0
	91.4	1	4.2	4.2	54.2
	93.4	1	4.2	4.2	58.3
	97.7	1	4.2	4.2	62.5
	97.8	1	4.2	4.2	66.7
	98.3	1	4.2	4.2	70.8
	98.4	1	4.2	4.2	75.0
	98.5	1	4.2	4.2	79.2
	98.9	1	4.2	4.2	83.3
	99.4	1	4.2	4.2	87.5
	99.7	1	4.2	4.2	91.7
	100.0	2	8.3	8.3	100.0
	Total	24	100.0	100.0	

Mean	80.042	Std err	5.662	Median	90.445
Mode	100.000	Std dev	27.736	Variance	769.309
Kurtosis	1.412	S E Kurt	.918	Skewness	-1.622
S E Skew	.472	Range	90.240	Minimum	9.760
Maximum	100.000	Sum	1921.000		

Valid cases 24 Missing cases 0

- -

ARISCORE Bracket score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
< 1/2 adhesive left	1.0	4	16.7	16.7	16.7
> 1/2 adhesive left	2.0	9	37.5	37.5	54.2
All base covered by	3.0	11	45.8	45.8	100.0
	Total	24	100.0	100.0	

Mean	2.292	Std err	.153	Median	2.000
Mode	3.000	Std dev	.751	Variance	.563
Kurtosis	-.950	S E Kurt	.918	Skewness	-.553
S E Skew	.472	Range	2.000	Minimum	1.000
Maximum	3.000	Sum	55.000		

Valid cases 24 Missing cases 0

For Treatment Group "ETD(M)"

VENSCORE Veneer score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
All of the composite	1.0	2	8.3	8.3	8.3
>10% but <90% compos	3.0	9	37.5	37.5	45.8
Less than 10% compos	4.0	10	41.7	41.7	87.5
No composite remaine	5.0	3	12.5	12.5	100.0
	Total	24	100.0	100.0	

Mean	3.500	Std err	.209	Median	4.000
Mode	4.000	Std dev	1.022	Variance	1.043
Kurtosis	1.466	S E Kurt	.918	Skewness	-.934
S E Skew	.472	Range	4.000	Minimum	1.000
Maximum	5.000	Sum	84.000		

Valid cases 24 Missing cases 0

VENTHIC Veneer thickness

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.3	2	8.3	8.3	8.3
	.4	2	8.3	8.3	16.7
	.5	13	54.2	54.2	70.8
	.6	7	29.2	29.2	100.0
	Total	24	100.0	100.0	

Mean	.504	Std err	.018	Median	.500
Mode	.500	Std dev	.086	Variance	.007
Kurtosis	1.032	S E Kurt	.918	Skewness	-.983
S E Skew	.472	Range	.300	Minimum	.300
Maximum	.600	Sum	12.100		

Valid cases 24 Missing cases 0

TOOTH8R ARI Tooth #8R

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	13	54.2	54.2	54.2
	5.0	3	12.5	12.5	66.7
	10.0	3	12.5	12.5	79.2
	15.0	1	4.2	4.2	83.3
	25.0	1	4.2	4.2	87.5
	60.0	1	4.2	4.2	91.7
	80.0	1	4.2	4.2	95.8
	90.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	13.125	Std err	5.246	Median	.000
Mode	.000	Std dev	25.699	Variance	660.462
Kurtosis	4.354	S E Kurt	.918	Skewness	2.311
S E Skew	.472	Range	90.000	Minimum	.000
Maximum	90.000	Sum	315.000		

Valid cases 24 Missing cases 0

For Treatment Group "ETO(M)"

TOOTHCO   ARI Tooth # CO

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	11	45.8	45.8	45.8
	5.0	3	12.5	12.5	58.3
	10.0	2	8.3	8.3	66.7
	15.0	3	12.5	12.5	79.2
	20.0	2	8.3	8.3	87.5
	25.0	1	4.2	4.2	91.7
	33.0	1	4.2	4.2	95.8
	50.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	9.500	Std err	2.623	Median	5.000
Mode	.000	Std dev	12.850	Variance	165.130
Kurtosis	3.131	S E Kurt	.918	Skewness	1.704
S E Skew	.472	Range	50.000	Minimum	.000
Maximum	50.000	Sum	228.000		

Valid cases 24   Missing cases 0

- -

TOOTHUR   ARI Tooth # UR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	1	4.2	4.2	4.2
	10.0	1	4.2	4.2	8.3
	25.0	1	4.2	4.2	12.5
	40.0	1	4.2	4.2	16.7
	50.0	1	4.2	4.2	20.8
	66.0	1	4.2	4.2	25.0
	70.0	1	4.2	4.2	29.2
	80.0	2	8.3	8.3	37.5
	85.0	1	4.2	4.2	41.7
	90.0	2	8.3	8.3	50.0
	95.0	6	25.0	25.0	75.0
	100.0	6	25.0	25.0	100.0
	Total	24	100.0	100.0	

Mean	77.333	Std err	6.157	Median	92 500
Mode	95.000	Std dev	30.163	Variance	909.797
Kurtosis	1.242	S E Kurt	.918	Skewness	-1.517
S E Skew	.472	Range	100.000	Minimum	000
Maximum	100.000	Sum	1856.000		

Valid cases 24   Missing cases 0

For Treatment Group "ETD(M)"
VENDAM Veneer Damage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1.0	3	12.5	12.5	12.5
	2.0	21	87.5	87.5	100 0
	Total	24	100.0	100.0	

Mean	1.875	Std err	.069	Median	2.000
Mode	2.000	Std dev	.338	Variance	.114
Kurtosis	4.210	S E Kurt	.918	Skewness	-2.422
S E Skew	.472	Range	1.000	Minimum	1.000
Maximum	2.000	Sum	45.000		

Valid cases 24 Missing cases 0

For Treatment Group "ETD(C)"
ARIBRACK ARI percentage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	4.4	1	4.2	4.2	4.2
	4.4	1	4.2	4.2	8.3
	6.3	1	4.2	4.2	12.5
	9.2	1	4.2	4.2	16.7
	11.4	1	4.2	4.2	20.8
	11.8	1	4.2	4.2	25.0
	12.8	1	4.2	4.2	29.2
	23.0	1	4.2	4.2	33.3
	26.2	1	4.2	4.2	37.5
	32.8	1	4.2	4.2	41.7
	33.3	1	4.2	4.2	45.8
	36.2	1	4.2	4.2	50.0
	60.4	1	4.2	4.2	54.2
	63.2	1	4.2	4.2	58.3
	66.4	1	4.2	4.2	62.5
	66.8	1	4.2	4.2	66.7
	70.4	1	4.2	4.2	70.8
	78.5	1	4.2	4.2	75.0
	79.5	1	4.2	4.2	79.2
	83.5	1	4.2	4.2	83.3
	94.0	1	4.2	4.2	87.5
	95.0	1	4.2	4.2	91.7
	97.7	1	4.2	4.2	95.8
	98.9	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	48.567	Std err	6.967	Median	48.295
Mode	4.360	Std dev	34.133	Variance	1165.042
Kurtosis	-1.590	S E Kurt	.918	Skewness	.085
S E Skew	.472	Range	94.580	Minimum	4.360
Maximum	98.940	Sum	1165.610		

Valid cases 24 Missing cases 0

For Treatment Group "ETO(C)"

ARISCORE Bracket score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
< 1/2 adhesive left	1.0	12	50.0	50.0	50.0
> 1/2 adhesive left	2.0	11	45.8	45.8	95.8
All base covered by	3.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	1.542	Std err	.120	Median	1.500
Mode	1.000	Std dev	.588	Variance	.346
Kurtosis	-.586	S E Kurt	.918	Skewness	.325
S E Skew	.472	Range	2.000	Minimum	1.000
Maximum	3.000	Sum	37.000		

Valid cases 24 Missing cases 0

- -

VENSCORE Veneer score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
All of the composite	1.0	6	25.0	25.0	25.0
Greater than 90% com	2.0	8	33.3	33.3	58.3
>10% but <90% compos	3.0	9	37.5	37.5	95.8
Less than 10% compos	4.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	2.208	Std err	.180	Median	2.000
Mode	3.000	Std dev	.884	Variance	.781
Kurtosis	-.967	S E Kurt	.918	Skewness	-.030
S E Skew	.472	Range	3.000	Minimum	1.000
Maximum	4.000	Sum	53.000		

Valid cases 24 Missing cases 0

- -

VENTHIC Veneer thickness

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.2	1	4.2	4.2	4.2
	.3	2	8.3	8.3	12.5
	.4	3	12.5	12.5	25.0
	.5	11	45.8	45.8	70.8
	.6	6	25.0	25.0	95.8
	.7	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	.492	Std err	.023	Median	.500
Mode	.500	Std dev	.114	Variance	.013
Kurtosis	.880	S E Kurt	.918	Skewness	-.788
S E Skew	.472	Range	.500	Minimum	.200
Maximum	.700	Sum	11.800		

Valid cases 24 Missing cases 0

For Treatment Group "ETD(C)"
TOOTHBR ARI Tooth %BR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	3	12.5	12.5	12.5
	5.0	1	4.2	4.2	16.7
	10.0	3	12.5	12.5	29.2
	25.0	1	4.2	4.2	33.3
	33.0	1	4.2	4.2	37.5
	35.0	1	4.2	4.2	41.7
	40.0	1	4.2	4.2	45.8
	50.0	1	4.2	4.2	50.0
	66.0	3	12.5	12.5	62.5
	80.0	1	4.2	4.2	66.7
	85.0	1	4.2	4.2	70.8
	90.0	2	8.3	8.3	79.2
	95.0	4	16.7	16.7	95.8
	100.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	51.708	Std err	7.636	Median	58.000
Mode	95.000	Std dev	37.409	Variance	1399.433
Kurtosis	-1.653	S E Kurt	.918	Skewness	-.134
S E Skew	.472	Range	100.000	Minimum	.000
Maximum	100.000	Sum	1241.000		

Valid cases 24 Missing cases 0

TOOTHCO ARI Tooth % CO

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	9	37.5	37.5	37.5
	5.0	2	8.3	8.3	45.8
	10.0	3	12.5	12.5	58.3
	15.0	1	4.2	4.2	62.5
	20.0	1	4.2	4.2	66.7
	25.0	2	8.3	8.3	75.0
	33.0	2	8.3	8.3	83.3
	40.0	1	4.2	4.2	87.5
	50.0	1	4.2	4.2	91.7
	60.0	1	4.2	4.2	95.8
	90.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	17.958	Std err	4.752	Median	10.000
Mode	.000	Std dev	23.278	Variance	541.868
Kurtosis	2.808	S E Kurt	.918	Skewness	1.659
S E Skew	.472	Range	90.000	Minimum	.000
Maximum	90.000	Sum	431.000		

Valid cases 24 Missing cases 0

For Treatment Group "ETD(C)"
TOOTHUR ARI Tooth # UR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	8	33.3	33.3	33.3
	5.0	4	16.7	16.7	50.0
	10.0	1	4.2	4.2	54.2
	15.0	1	4.2	4.2	58.3
	20.0	1	4.2	4.2	62.5
	33.0	1	4.2	4.2	66.7
	66.0	1	4.2	4.2	70.8
	70.0	1	4.2	4.2	75.0
	75.0	3	12.5	12.5	87.5
	80.0	1	4.2	4.2	91.7
	90.0	1	4.2	4.2	95.8
	95.0	1	4.2	4.2	100.0
	Total	24	100.0	100.0	

Mean	30.167	Std err	7.339	Median	7.500
Mode	.000	Std dev	35.952	Variance	1292.580
Kurtosis	-1.360	S E Kurt	.918	Skewness	.708
S E Skew	.472	Range	95.000	Minimum	.000
Maximum	95.000	Sum	724.000		

Valid cases 24 Missing cases 0

- -

VENDAM Veneer Damage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	2.0	24	100.0	100.0	100.0
	Total	24	100.0	100.0	

Mean	2.000	Std err	.000	Median	2.000
Mode	2.000	Std dev	.000	Variance	.000
Range	.000	Minimum	2.000	Maximum	2.000
Sum	48.000				

Valid cases 24 Missing cases 0

```
T-TEST /GROUPS= TREATGP (4,5) / VARIABLES= TEMPINC.

t-tests for independent samples of  TREATGP   Treatment group

GROUP 1 - TREATGP  EQ    4.0:  ETD(M)
GROUP 2 - TREATGP  EQ    5.0:  ETD(C)
```

Variable	Number of Cases	Mean	Standard Deviation	Standard Error
TEMPINC Temperature increase				
GROUP 1	24	6.5458	3.811	.778
GROUP 2	24	3.5458	1.203	.245

		Pooled Variance Estimate			Separate Variance Estimate		
F Value	2-tail Prob.	t Value	Degrees of Freedom	2-tail Prob.	t Value	Degrees of Freedom	2-tail Prob.
10.04	.000	3.68	46	.001	3.68	27 53	.001

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
     Variable  ARISCORE   Bracket score
  By Variable  TREATGP    Treatment group

                             ANALYSIS OF VARIANCE

                                    SUM OF          MEAN               F      F
       SOURCE              D.F.    SQUARES         SQUARES          RATIO   PROB.

BETWEEN GROUPS               3      15.4911         5.1837         14.4078  .0000

WITHIN GROUPS               91      32.6141          .3584

TOTAL                       94      48.1053
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
     Variable  ARISCORE   Bracket score
  By Variable  TREATGP    Treatment group


MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          4.03   4.03   4.03

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        0.4233 * RANGE * DSQRT(1/N(I) + 1/N(J))

   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                         B D E E
                             T T
                             D D
                             ( (
                             C M
                             ) )
    Mean       Group

    1.2083     B
    1.4783     D
    1.5417     ETD(C)
    2.2917     ETD(M)      * * *
```

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
      Variable  ARIBRACK    ARI percentage
   By Variable  TREATGP     Treatment group
```

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	3	35080.2414	11693.4138	14.4530	.0000
WITHIN GROUPS	91	73625.1452	809.0675		
TOTAL	94	108705.3866			

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
      Variable  ARIBRACK    ARI percentage
   By Variable  TREATGP     Treatment group
```

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

4.03 4.03 4.03

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
20.1130 * RANGE * DSQRT(1/N(I) + 1/N(J))

(*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

```
                           B D E E
                               T T
                               D D
                               ( (
                               C M
                               ) )
    Mean        Group

  27.1088      B
  44.1217      D
  48.5671      ETD(C)
  80.0417      ETD(M)      * * *
```

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - -
    Variable  VENSCORE   Veneer score
 By Variable  TREATGP    Treatment group

                              ANALYSIS OF VARIANCE
```

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	3	50.2742	16.7581	22.0174	.0000
WITHIN GROUPS	91	69.2627	.7611		
TOTAL	94	119.5368			

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - -
    Variable  VENSCORE   Veneer score
 By Variable  TREATGP    Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          4.03   4.03   4.03

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
       0.6169 * RANGE * DSQRT(1/N(I) + 1/N(J))

  (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                              B D E E
                                  T T
                                  D D
                                  ( (
                                  C M
                                  ) )
   Mean       Group

   1.5000     B
   2.1739     D
   2.2083     ETD(C)
   3.5000     ETD(M)      * * *
```

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - -
      Variable  TOOTHBR    ARI Tooth #BR
   By Variable  TREATGP    Treatment group

                              ANALYSIS OF VARIANCE

                               SUM OF          MEAN             F        F
        SOURCE          D.F.   SQUARES         SQUARES          RATIO    PROB.

BETWEEN GROUPS            4    67068.4448     16767.1112       25.9010   .0000

WITHIN GROUPS           114    73798.1938       647.3526

TOTAL                   118   140866.6387

- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - -
      Variable  TOOTHBR    ARI Tooth #BR
   By Variable  TREATGP    Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          4.43    4.43    4.43    4.43

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
      17.9910 * RANGE * DSQRT(1/N(I) + 1/N(J))

  (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                        C E D E B
                        o T   T
                        n D   D
                        t (   (
                        r M   C
                        o )   )
                        l
   Mean       Group

     .0000    Control
   13.1250    ETD(M)
   48.4348    D         * *
   51.7083    ETD(C)    * *
   60.2917    B         * *
```

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
      Variable   TOOTHCO     ARI Tooth % CO
   By Variable   TREATGP     Treatment group
```

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB
BETWEEN GROUPS	4	14673.0660	3668.2665	12.4389	.0000
WITHIN GROUPS	114	33618.9004	294.9026		
TOTAL	118	48291.9664			

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
      Variable   TOOTHCO     ARI Tooth % CO
   By Variable   TREATGP     Treatment group
```

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

4.43   4.43   4.43   4.43

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
12.1430 * RANGE * DSQRT(1/N(I) + 1/N(J))

(*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

Mean	Group	Control	ETD(M)	ETD(C)	D	B
.0000	Control					
9.5000	ETD(M)					
17.9583	ETD(C)	*				
27.8696	D	*	*			
29.3333	B	*	*			

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
     Variable  TOOTHVR    ARI Tooth % VR
  By Variable  TREATGP    Treatment group

                               ANALYSIS OF VARIANCE

                                 SUM OF          MEAN               F       F
      SOURCE            D.F.     SQUARES         SQUARES            RATIO   PROB.

BETWEEN GROUPS            4      85278.0601      21319.5150         31.5146 .0000

WITHIN GROUPS           114      77120.4946        676.4956

TOTAL                   118     162398.5546

- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
     Variable  TOOTHVR    ARI Tooth % VR
  By Variable  TREATGP    Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          4.43    4.43    4.43    4.43

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
        18.3915 * RANGE * DSQRT(1/N(I) + 1/N(J))

  (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                           C B D E E
                           o     T T
                           n     D D
                           t     ( (
                           r     C M
                           o     ) )
                           l
    Mean       Group

     .0000     Control
   10.2917     B
   23.6957     D
   30.1667     ETD(C)      *
   77.3333     ETD(M)      * * * *
```

```
- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - -
    Variable  VENDAM      Veneer Damage
 By Variable  TREATGP     Treatment group

                          ANALYSIS OF VARIANCE

                                 SUM OF         MEAN            F        F
     SOURCE            D.F.      SQUARES        SQUARES       RATIO    PROB.

BETWEEN GROUPS           4        2.0480         .5120       4.9462    .0010
WITHIN GROUPS          114       11.8007         .1035
TOTAL                  118       13.8487

- - - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - -
    Variable  VENDAM      Veneer Damage
 By Variable  TREATGP     Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          4.43   4.43   4.43   4.43

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
      0.2275 * RANGE * DSQRT(1/N(I) + 1/N(J))

   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                               D B E C E
                                   T o T
                                   D n D
                                   ( t (
                                   M r C
                                   ) o )
                                     l

   Mean        Group

   1.6522      D
   1.7917      B
   1.9750      ETD(M)
   2.0000      Control       *
   2.0000      ETD(C)        *
```

TREATMENT GROUP 'B'

-- Correlation Coefficients --

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000	.5018*	.5320**	.0491	-.6824**	.0758
ARISCORE	.5018*	1.0000	.7152**	.3798	-.5998**	.1641
VENSCORE	.5320**	.7152**	1.0000	.2206	-.5669**	-.0279
VENTHIC	.0491	.3798	.2206	1.0000	.0582	-.1913
TOOTHBR	-.6824**	-.5998**	-.5669**	.0582	1.0000	-.6650**
TOOTHCO	.0758	.1641	-.0279	-.1913	-.6650**	1.0000
TOOTHVR	.8152**	.6166**	.7740**	.1245	-.6092**	-.1871
VENDAM	-.2677	-.2421	-.0795	.0876	.5087*	-.3906

* - Signif. LE .05   ** - Signif. LE .01   (2-tailed)

" . " is printed if a coefficient cannot be computed

	TOOTHVR	VENDAM
ARIBRACK	.8152**	-.2677
ARISCORE	.6166**	-.2421
VENSCORE	.7740**	-.0795
VENTHIC	.1245	.0876
TOOTHBR	-.6092**	.5087*
TOOTHCO	-.1871	-.3906
TOOTHVR	1.0000	-.2525
VENDAM	-.2525	1.0000

* - Signif. LE .05   ** - Signif. LE .01   (2-tailed)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'B'

- - Correlation Coefficients - -

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000	.5018	.5320	.0491	-.6824	0758
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .	P= .012	P= .007	P= .820	P= .000	P= .725
ARISCORE	.5018	1.0000	.7152	.3798	-.5998	.1641
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .012	P= .	P= .000	P= .067	P= .002	P= .443
VENSCORE	.5320	.7152	1.0000	.2206	-.5669	-.0279
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .007	P= .000	P= .	P= .300	P= .004	P= .897
VENTHIC	.0491	.3798	.2206	1.0000	0582	-.1913
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .820	P= .067	P= .300	P= .	P= .787	P= .370
TOOTHBR	-.6824	-.5998	-.5669	.0582	1.0000	-.6650
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .000	P= .002	P= .004	P= .787	P= .	P= 000
TOOTHCO	.0758	.1641	-.0279	-.1913	-.6650	1 0000
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .725	P= .443	P= .897	P= .370	P= .000	P=
TOOTHVR	.8152	.6166	.7740	.1245	-.6092	-.1871
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .000	P= .001	P= .000	P= .562	P= .002	P= 381
VENDAM	-.2677	-.2421	-.0795	.0876	.5087	-.3906
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .206	P= .254	P= .712	P= .684	P= .011	P= .059

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'B'

-- Correlation Coefficients --

	TOOTHUR	VENDAM
ARIBRACK	.8152	-.2677
	(24)	(24)
	P= .000	P= .206
ARISCORE	.6166	-.2421
	(24)	(24)
	P= .001	P= .254
VENSCORE	.7740	-.0795
	(24)	(24)
	P= .000	P= .712
VENTHIC	.1245	.0876
	(24)	(24)
	P= .562	P= .684
TOOTHBR	-.6092	.5087
	(24)	(24)
	P= .002	P= .011
TOOTHCO	-.1871	-.3906
	(24)	(24)
	P= .381	P= .059
TOOTHUR	1.0000	-.2525
	(24)	(24)
	P= .	P= .234
VENDAM	-.2525	1.0000
	(24)	(24)
	P= .234	P= .

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'D'

- - Correlation Coefficients - -

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000	.8953**	.5457**	-.3797	-.6457**	-.2651
ARISCORE	.8953**	1.0000	.6124**	-.4547*	-.6540**	-.3606
VENSCORE	.5457**	.6124**	1.0000	-.3801	-.6030**	-.5035*
VENTHIC	-.3797	-.4547*	-.3801	1.0000	.4951*	.2923
TOOTHBR	-.6457**	-.6540**	-.6030**	.4951*	1.0000	-.0035
TOOTHCO	-.2651	-.3606	-.5035*	.2923	-.0035	1.0000
TOOTHVR	.6686**	.7343**	.7865**	-.5630**	-.7691**	-.6361**
VENDAM	-.2500	-.3421	-.1693	.0000	.1271	.2363

* - Signif. LE .05   ** - Signif. LE .01   (2-tailed)

" . " is printed if a coefficient cannot be computed

	TOOTHVR	VENDAM
ARIBRACK	.6686**	-.2500
ARISCORE	.7343**	-.3421
VENSCORE	.7865**	-.1693
VENTHIC	-.5630**	.0000
TOOTHBR	-.7691**	.1271
TOOTHCO	-.6361**	.2363
TOOTHVR	1.0000	-.2456
VENDAM	-.2456	1.0000

* - Signif. LE .05   ** - Signif. LE .01   (2-tailed)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'D'

- - Correlation Coefficients - -

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000 (23) P= .	.8953 (23) P= .000	.5457 (23) P= .007	-.3797 (23) P= .074	-.6457 (23) P= .001	-.2651 (23) P= .221
ARISCORE	.8953 (23) P= .000	1.0000 (23) P= .	.6124 (23) P= .002	-.4547 (23) P= .029	-.6540 (23) P= .001	-.3606 (23) P= .091
VENSCORE	.5457 (23) P= .007	.6124 (23) P= .002	1.0000 (23) P= .	-.3801 (23) P= .074	-.6030 (23) P= .002	-.5035 (23) P= .014
VENTHIC	-.3797 (23) P= .074	-.4547 (23) P= .029	-.3801 (23) P= .074	1.0000 (23) P= .	.4951 (23) P= .016	.2923 (23) P= .176
TOOTHBR	-.6457 (23) P= .001	-.6540 (23) P= .001	-.6030 (23) P= .002	.4951 (23) P= .016	1.0000 (23) P= .	-.0035 (23) P= .987
TOOTHCO	-.2651 (23) P= .221	-.3606 (23) P= .091	-.5035 (23) P= .014	.2923 (23) P= .176	-.0035 (23) P= .987	1.0000 (23) P= .
TOOTHVR	.6686 (23) P= .000	.7343 (23) P= .000	.7865 (23) P= .000	-.5630 (23) P= .005	-.7691 (23) P= .000	-.6361 (23) P= .001
VENDAM	-.2500 (23) P= .250	-.3421 (23) P= .110	-.1693 (23) P= .440	.0000 (23) P=1.000	.1271 (23) P= .563	.2363 (23) P= .278

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'D'

-- Correlation Coefficients --

	TOOTHVR	VENDAM
ARIBRACK	.6686	-.2500
	(23)	(23)
	P= .000	P= .250
ARISCORE	.7343	-.3421
	(23)	(23)
	P= .000	P= .110
VENSCORE	.7865	-.1693
	(23)	(23)
	P= .000	P= .440
VENTHIC	-.5630	.0000
	(23)	(23)
	P= .005	P=1.000
TOOTHBR	-.7691	.1271
	(23)	(23)
	P= .000	P= .563
TOOTHCO	-.6361	.2363
	(23)	(23)
	P= .001	P= .278
TOOTHVR	1.0000	-.2456
	(23)	(23)
	P= .	P= .259
VENDAM	-.2456	1.0000
	(23)	(23)
	P= .259	P= .

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'ETD(M)'

-- Correlation Coefficients --

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000	.8886**	.7735**	.2846	-.9208**	-.3735
ARISCORE	.8886**	1.0000	.7088**	.1827	-.7480**	-.4350*
VENSCORE	.7735**	.7088**	1.0000	.4709*	-.7991**	-.4107*
VENTHIC	.2846	.1827	.4709*	1.0000	-.3707	-.1753
TOOTHBR	-.9208**	-.7480**	-.7991**	-.3707	1.0000	.1261
TOOTHCO	-.3735	-.4350*	-.4107*	-.1753	.1261	1.0000
TOOTHVR	.9434**	.8232**	.8565**	.3906	-.9050**	-.5361**
VENDAM	.2272	.3215	.3150	.3185	-.2786	.0851

* - Signif. LE .05 ** - Signif. LE .01 (2-tailed)

" . " is printed if a coefficient cannot be computed

	TOOTHVR	VENDAM
ARIBRACK	.9434**	.2272
ARISCORE	.8232**	.3215
VENSCORE	.8565**	.3150
VENTHIC	.3906	.3185
TOOTHBR	-.9050**	-.2786
TOOTHCO	-.5361**	.0851
TOOTHVR	1.0000	.2005
VENDAM	.2005	1.0000

* - Signif. LE .05 ** - Signif. LE .01 (2-tailed)

" " is printed if a coefficient cannot be computed

TREATMENT GROUP 'ETD(M)'

- - Correlation Coefficients - -

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000	.8886	.7735	.2846	- 9208	-.3735
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .	P= .000	P= .000	P= .178	P= .000	P= .072
ARISCORE	.8886	1.0000	.7088	.1827	-.7480	-.4350
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .000	P= .	P= .000	P= .393	P= .000	P= .034
VENSCORE	.7735	.7088	1.0000	.4709	-.7991	-.4107
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .000	P= .000	P= .	P= .020	P= .000	P= .046
VENTHIC	.2846	.1827	.4709	1.0000	-.3707	-.1753
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .178	P= .393	P= .020	P= .	P= .075	P= .412
TOOTHBR	-.9208	-.7480	-.7991	-.3707	1.0000	.1261
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .000	P= .000	P= .000	P= .075	P= .	P= .557
TOOTHCO	-.3735	-.4350	-.4107	-.1753	.1261	1.0000
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .072	P= .034	P= .046	P= .412	P= .557	P= .
TOOTHVR	.9434	.8232	.8565	.3906	-.9050	-.5361
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .000	P= .000	P= .000	P= .059	P= .000	P= .007
VENDAM	.2272	.3215	.3150	.3185	-.2786	.0851
	(24)	(24)	(24)	(24)	(24)	(24)
	P= .286	P= .126	P= .134	P= .129	P= .187	P= .692

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'ETD(M)'

- - Correlation Coefficients - -

	TOOTHUR	VENDAM
ARIBRACK	.9434 (24) P= .000	.2272 (24) P= .286
ARISCORE	.8232 (24) P= .000	.3215 (24) P= .126
VENSCORE	.8565 (24) P= .000	.3150 (24) P= .134
VENTHIC	.3906 (24) P= .059	.3185 (24) P= .129
TOOTHBR	-.9050 (24) P= .000	-.2786 (24) P= .187
TOOTHCU	-.5361 (24) P= .007	.0851 (24) P= .692
TOOTHUR	1.0000 (24) P= .	.2005 (24) P= .347
VENDAM	.2005 (24) P= .347	1.0000 (24) P= .

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

TREATMENT GROUP 'ETD(M)'

- - Correlation Coefficients - -

	ARIBRACK	ARISCORE	VENSCORE	VENTHIC	TOOTHBR	TOOTHCO
ARIBRACK	1.0000 (24) P= .	.8886 (24) P= .000	.7735 (24) P= .000	.2846 (24) P= .178	- 9208 (24) P= .000	-.3735 (24) P= .072
ARISCORE	.8886 (24) P= .000	1.0000 (24) P= .	.7088 (24) P= .000	.1827 (24) P= .393	-.7480 (24) P= .000	-.4350 (24) P= .034
VENSCORE	.7735 (24) P= .000	.7088 (24) P= .000	1.0000 (24) P= .	.4709 (24) P= .020	-.7991 (24) P= .000	-.4107 (24) P= .046
VENTHIC	.2846 (24) P= .178	.1827 (24) P= .393	.4709 (24) P= .020	1.0000 (24) P= .	-.3707 (24) P= .075	-.1753 (24) P= .412
TOOTHBR	-.9208 (24) P= .000	-.7480 (24) P= .000	-.7991 (24) P= .000	-.3707 (24) P= .075	1.0000 (24) P= .	.1261 (24) P= .557
TOOTHCO	-.3735 (24) P= .072	-.4350 (24) P= .034	-.4107 (24) P= .046	-.1753 (24) P= .412	.1261 (24) P= .557	1.0000 (24) P= .
TOOTHVR	.9434 (24) P= .000	.8232 (24) P= .000	.8565 (24) P= .000	.3906 (24) P= .059	-.9050 (24) P= .000	-.5361 (24) P= .007
VENORM	.2272 (24) P= .286	.3215 (24) P= .126	.3150 (24) P= .134	.3185 (24) P= .129	-.2786 (24) P= .187	.0851 (24) P= .692

(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
1	0.5	0.5	0.5	0.5	0.5
2	0.5	0.4	0.4	0.5	0.5
3	0.6	0.5	0.5	0.5	0.5
4	0.6	0.6	0.6	0.5	0.5
5	0.3	0.3	0.3	0.5	0.5
6	0.7	0.6	0.6	0.6	0.6
7	0.5	0.5	0.5	0.5	0.4
8	0.5	0.5	0.5	0.5	0.4
9	0.3	0.3	0.3	0.3	0.5
10	0.4	0.3	0.3	0.3	0.3
11	0.5	0.4	0.4	0.4	0.4
12	0.3	0.4	0.3	0.5	0.5
13	0.5	0.5	0.5	0.5	0.6
14	0.5	0.5	0.5	0.4	0.6
15	0.5	0.5	0.5	0.4	0.5
16	0.4	0.4	0.4	0.4	0.6
17	0.5	0.5	0.5	0.5	0.4
18	0.5	0.4	0.3	0.4	0.3
19	0.5	0.5	0.5	0.5	0.5
20	0.5	0.5	0.4	0.3	0.5

1.	192.5	36.	185.5	71.	184.4	106.	183.2
2.	179.0	37.	179.8	72.	179.3	107.	188.2
3.	187.9	38.	172.4	73.	184.3	108.	181.5
4.	183.1	39.	183.2	74.	186.2	109.	187.6
5.	181.5	40.	177.5	75.	185.1	110.	177.6
6.	191.2	41.	191.0	76.	184.7	111.	178.5
7.	188.4	42.	188.8	77.	175.8	112.	183.2
8.	171.7	43.	187.6	78.	181.4	113.	186.1
9.	181.1	44.	188.5	79.	174.5	114.	186.6
10.	170.3	45.	178.0	80.	181.7	115.	195.0
11.	187.7	46.	178.8	81.	177.9	116.	184.4
12.	187.5	47.	181.8	82.	179.8		
13.	180.7	48.	183.1	83.	180.4		
14.	173.6	49.	186.9	84.	183.4		
15.	187.0	50.	180.0	85.	187.0		
16.	190.4	51.	179.1	86.	178.4		
17.	185.1	52.	185.2	87.	178.4		
18.	185.4	53.	184.9	88.	177.7		
19.	186.0	54.	184.4	89.	176.1		
20.	187.7	55.	179.0	90.	180.4		
21.	185.7	56.	183.0	91.	188.8		
22.	193.3	57.	190.2	92.	192.0		
23.	175.4	58.	180.1	93.	183.8		
24.	174.6	59.	191.2	94.	176.2		
25.	185.0	60.	190.7	95.	195.0		
26.	185.0	61.	182.1	96.	175.3		
27.	183.3	62.	176.4	97.	185.5		
28.	184.4	63.	171.5	98.	183.6		
29.	180.7	64.	187.6	99.	180.2		
30.	180.4	65.	184.2	100.	79.8		
31.	180.1	66.	181.7	101.	181.5		
32.	184.4	67.	185.5	102.	177.2		
33.	186.9	68.	185.5	103.	185.9		
34.	189.9	69.	178.3	104.	185.3		
35.	189.2	70.	183.6	105.	184.6		

Test #1 (Battery #2 Tip #1 @ 5 sec) 116 trials **Average = 21246.7/116 = 183.2°C**

For Treatment Group "D"

ARISCORE Bracket score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
< 1/2 adhesive left	1.0	13	56.5	56.5	56.5
> 1/2 adhesive left	2.0	9	39.1	39.1	95.7
All base covered by	3.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	1.478	Std err	.124	Median	1.000
Mode	1.000	Std dev	.593	Variance	.352
Kurtosis	-.218	S E Kurt	.935	Skewness	.806
S E Skew	.481	Range	2.000	Minimum	1.000
Maximum	3.000	Sum	34.000		

Valid cases 23 Missing cases 0

- -

VENSCORE Veneer score

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
All of the composite	1.0	6	26.1	26.1	26.1
Greater than 90% com	2.0	8	34.8	34.8	60.9
>10% but <90% compos	3.0	8	34.8	34.8	95.7
Less than 10% compos	4.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	2.174	Std err	.185	Median	2.000
Mode	2.000	Std dev	.887	Variance	.787
Kurtosis	-.923	S E Kurt	.935	Skewness	.061
S E Skew	.481	Range	3.000	Minimum	1.000
Maximum	4.000	Sum	50.000		

Valid cases 23 Missing cases 0

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
     Variable  ARIBRACK   ARI percentage
  By Variable  TREATGP    Treatment group

                          ANALYSIS OF VARIANCE

                                 SUM OF        MEAN          F       F
     SOURCE           D.F.      SQUARES       SQUARES      RATIO   PROB.

BETWEEN GROUPS          3     35080.2414    11693.4138    14.4530  .0000

WITHIN GROUPS          91     73625.1452      809.0675

TOTAL                  94    108705.3866

- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -
     Variable  ARIBRACK   ARI percentage
  By Variable  TREATGP    Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

         4.03   4.03   4.03

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
      20.1130 * RANGE * DSQRT(1/N(I) + 1/N(J))

  (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                         B D E E
                             T T
                             D D
                             ( (
                             C M
                             ) )
   Mean      Group

  27.1088    B
  44.1217    D
  48.5671    ETD(C)
  80.0417    ETD(M)     * * *
```

TREATMENT GROUP 'ETD(M)'

- - Correlation Coefficients - -

	TOOTHVR	VENORM
ARIBRACK	.9434	.2272
	(24)	(24)
	P= .000	P= .286
ARISCORE	.8232	.3215
	(24)	(24)
	P= .000	P= .126
VENSCORE	.8565	.3150
	(24)	(24)
	P= .000	P= .134
VENTHIC	.3906	.3185
	(24)	(24)
	P= .059	P= .129
TOOTHBR	-.9050	-.2786
	(24)	(24)
	P= .000	P= .187
TOOTHCV	-.5361	.0851
	(24)	(24)
	P= .007	P= .692
TOOTHVR	1.0000	.2005
	(24)	(24)
	P= .	P= .347
VENORM	.2005	1.0000
	(24)	(24)
	P= .347	P= .

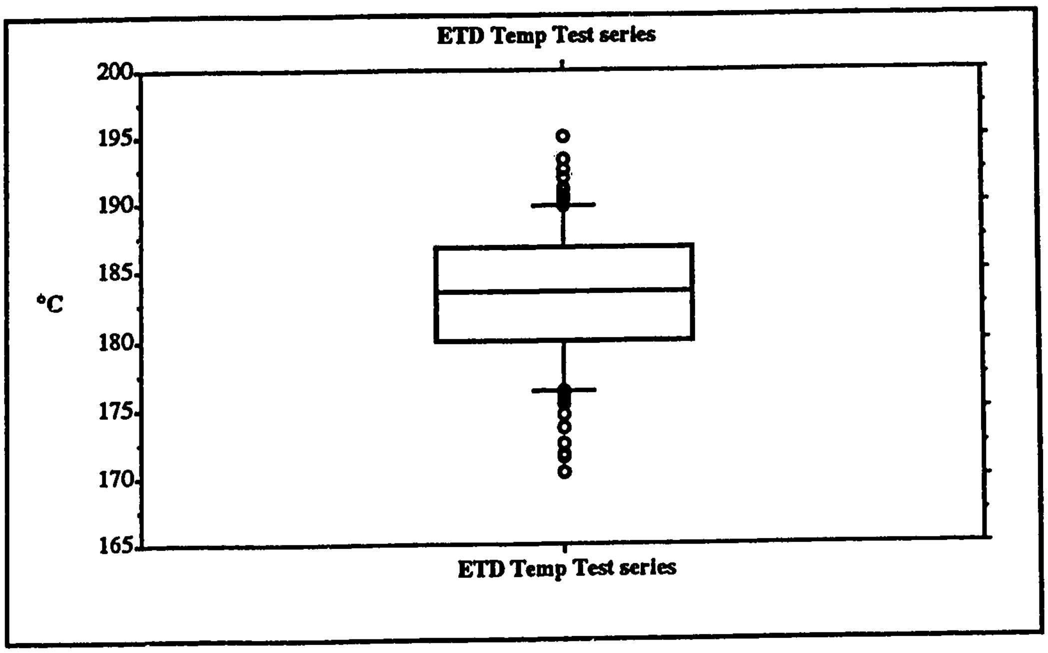
(Coefficient / (Cases) / 2-tailed sig)

" . " is printed if a coefficient cannot be computed

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
21	0.5	0.5	0.5	0.5	0.6
22	0.5	0.5	0.5	0.4	0.5
23	0.5	0.5	0.5	0.5	0.5
24	0.5	0.5	0.5	0.5	0.5
25	0.5	0.5	0.4	0.3	0.7
26	0.6	0.6	0.5	0.5	0.6
27	0.5	0.5	0.5	0.4	0.5
28	0.5	0.5	0.5	0.5	0.5
29	0.6	0.5	0.4	0.5	0.5
30	0.6	0.5	0.5	0.5	0.5
31	0.6	0.5	0.5	0.5	0.6
32	0.7	0.7	0.6	0.6	0.6
33	0.5	0.5	0.6	0.5	0.5
34	0.5	0.5	0.6	0.5	0.5
35	0.6	0.5	0.4	0.5	0.5
36	0.5	0.5	0.5	0.5	0.5
37	0.5	0.5	0.5	0.5	0.5
38	0.5	0.5	0.5	0.5	0.5
39	0.5	0.6	0.5	0.5	0.6
40	0.5	0.5	0.4	0.3	0.5

X_1: ETD Temp Test series

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
183.1612	5.1415	.4774	26.4346	2.8071	116
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
170.3	195	24.7	21246.7	3894611.19	0



For Treatment Group "D"
VENTHIC Veneer thickness

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.3	1	4.3	4.3	4.3
	.4	2	8.7	8.7	13.0
	.5	16	69.6	69.6	82.6
	.6	4	17.4	17.4	100.0
	Total	23	100.0	100.0	

Mean	.500	Std err	.014	Median	.500
Mode	.500	Std dev	.067	Variance	.005
Kurtosis	2.904	S E Kurt	.935	Skewness	-.975
S E Skew	.481	Range	.300	Minimum	.300
Maximum	.600	Sum	11.500		

Valid cases 23 Missing cases 0

- -

TOOTHBR ARI Tooth #BR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	2	8.7	8.7	8.7
	15.0	1	4.3	4.3	13.0
	33.0	1	4.3	4.3	17.4
	40.0	2	8.7	8.7	26.1
	50.0	11	47.8	47.8	73.9
	60.0	1	4.3	4.3	78.3
	66.0	1	4.3	4.3	82.6
	70.0	2	8.7	8.7	91.3
	80.0	1	4.3	4.3	95.7
	90.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	48.435	Std err	4.515	Median	50.000
Mode	50.000	Std dev	21.652	Variance	468.802
Kurtosis	1.122	S E Kurt	.935	Skewness	-.683
S E Skew	.481	Range	90.000	Minimum	.000
Maximum	90.000	Sum	1114.000		

Valid cases 23 Missing cases 0

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -
    Variable  VENSCORE    Veneer score
 By Variable  TREATGP     Treatment group

                               ANALYSIS OF VARIANCE
```

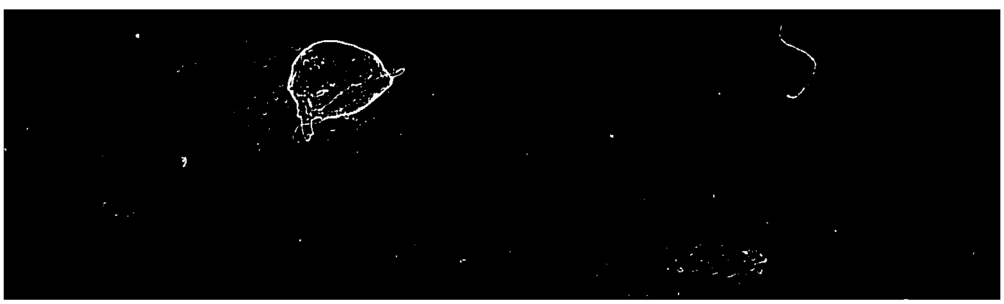
SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	3	50.2742	16.7581	22.0174	.0000
WITHIN GROUPS	91	69.2627	.7611		
TOTAL	94	119.5368			

```
- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - -
    Variable  VENSCORE    Veneer score
 By Variable  TREATGP     Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

         4.03   4.03   4.03

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
      0.6169 * RANGE * DSQRT(1/N(I) + 1/N(J))

  (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                         B D E E
                             T T
                             D D
                             ( (
                             C M
                             ) )
   Mean      Group

   1.5000    B
   2.1739    D
   2.2083    ETD(C)
   3.5000    ETD(M)      * * *
```

END

11-03-96

FIN



Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
41	0.4	0.5	0.4	0.5	0.4
42	0.5	0.4	0.5	0.5	0.4
43	0.4	0.5	0.5	0.5	0.5
44	0.5	0.5	0.5	0.4	0.5
45	0.3	0.4	0.5	0.4	0.3
46	0.6	0.7	0.6	0.7	0.7
47	0.6	0.5	0.6	0.5	0.6
48	0.5	0.6	0.6	0.6	0.7
49	0.6	0.7	0.7	0.6	0.7
50	0.6	0.6	0.6	0.5	0.4
51	0.6	0.5	0.5	0.5	0.5
52	0.5	0.5	0.5	0.5	0.5
53	0.6	0.6	0.5	0.6	0.7
54	0.5	0.5	0.5	0.6	0.5
55	0.5	0.5	0.5	0.6	0.6
56	0.6	0.6	0.5	0.5	0.5
57	0.5	0.5	0.5	0.5	0.4
58	0.5	0.5	0.5	0.5	0.6
59	0.5	0.5	0.5	0.5	0.5
60	0.7	0.7	0.5	0.5	0.7

1. 180.4
2. 191.6
3. 192.9
4. 186.8
5. 189.6

6. 192.0
7. 184.4
8. 183.9
9. 183.7
10. 182.4

11. 185.9
12. 184.2
13. 186.0
14. 190.4
15. 193.6

16. 194.9
17. 182.7
18. 186.8
19. 188.9
20. 190.4

21. 184.1
22. 184.3
23. 187.6
24. 201.3
25. 178.7

26. 185.1
27. 191.9
28. 189.8
29. 179.5
30. 189.1

31. 189.3
32. 191.4
33. 190.6
34. 192.5
35. 190.3

36. 176.4
37. 182.4
38. 189.3
39. 189.1
40. 174.8

41. 192.8
42. 195.1
43. 187.5
44. 192.4
45. 198.4

46. 181.9
47. 181.9
48. 190.1
49. 185.9
50. 186.8

51. 183.2
52. 183.2
53. 189.8
54. 185.8
55. 186.6

56. 188.1
57. 183.7
58. 197.7
59. 184.6
60. 188.2

61. 179.1
62. 186.1
63. 190.5
64. 181.3
65. 181.3

66. 178.0
67. 177.3
68. 181.8
69. 175.9
70. 178.9

71. 181.2
72. 180.7
73. 175.6
74. 182.6
75. 183.0

76. 177.8
77. 185.6
78. 172.8
79. 180.2
80. 184.2

81. 182.1
82. 176.0
83. 184.7
84. 184.3
85. 183.9

86. 188.1
87. 173.4
88. 187.5
89. 175.5
90. 182.5

91. 180.6
92. 185.9
93. 178.1
94. 182.4
95. 184.0

96. 182.8
97. 180.3
98. 176.9
99. 192.4
100. 181.8

101. 182.9
102. 184.4
103. 176.5
104. 177.6
105. 187.0

106. 179.2
107. 188.0
108. 188.7
109. 178.9
110. 184.6

111. 188.7
112. 179.6
113. 189.3
114. 193.6
115. 188.3

116. 186.4
117. 186.0
118. 182.1
119. 187.4
120. 187.0

121. 188.7
122. 183.6
123. 188.9
124. 191.9
125. 175.0

126. 180.3
127. 178.7
128. 182.4
129. 187.2
130. 179.9

131. 179.2
132. 182.0
133. 186.8
134. 180.1
135. 182.8

Test #2 (Battery #1 Tip #1 @ 5 sec) 135 trials   Average = 24953.5 / 135 = 184.8

For Treatment Group "D"

TOOTHCO ARI Tooth # CO

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	3	13.0	13.0	13.0
	5.0	2	8.7	8.7	21.7
	10.0	1	4.3	4.3	26.1
	20.0	2	8.7	8.7	34.8
	25.0	3	13.0	13.0	47.8
	30.0	1	4.3	4.3	52.2
	33.0	2	8.7	8.7	60.9
	40.0	4	17.4	17.4	78.3
	50.0	5	21.7	21.7	100.0
	Total	23	100.0	100.0	

Mean	27.870	Std err	3.703	Median	30.000
Mode	50.000	Std dev	17.750	Variance	315.391
Kurtosis	-1.203	S E Kurt	.935	Skewness	-.302
S E Skew	.481	Range	50.000	Minimum	.000
Maximum	50.000	Sum	641.000		

Valid cases 23 Missing cases 0

- -

TOOTHUR ARI Tooth # UR

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.0	7	30.4	30.4	30.4
	2.0	1	4.3	4.3	34.8
	10.0	3	13.0	13.0	47.8
	20.0	2	8.7	8.7	56.5
	25.0	2	8.7	8.7	65.2
	30.0	3	13.0	13.0	78.3
	33.0	1	4.3	4.3	82.6
	45.0	1	4.3	4.3	87.0
	75.0	1	4.3	4.3	91.3
	85.0	1	4.3	4.3	95.7
	95.0	1	4.3	4.3	100.0
	Total	23	100.0	100.0	

Mean	23.696	Std err	5.818	Median	20.000
Mode	.000	Std dev	27.903	Variance	778.585
Kurtosis	1.436	S E Kurt	.935	Skewness	1.439
S E Skew	.481	Range	95.000	Minimum	.000
Maximum	95.000	Sum	545.000		

Valid cases 23 Missing cases 0

- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -

Variable TOOTHBR   ARI Tooth %BR
By Variable TREATGP   Treatment group

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	4	67068.4448	16767.1112	25.9010	.0000
WITHIN GROUPS	114	73798.1938	647.3526		
TOTAL	118	140866.6387			

- - - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - -

Variable TOOTHBR   ARI Tooth %BR
By Variable TREATGP   Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

4.43   4.43   4.43   4.43

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
17.9910 * RANGE * DSQRT(1/N(I) + 1/N(J))

(*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

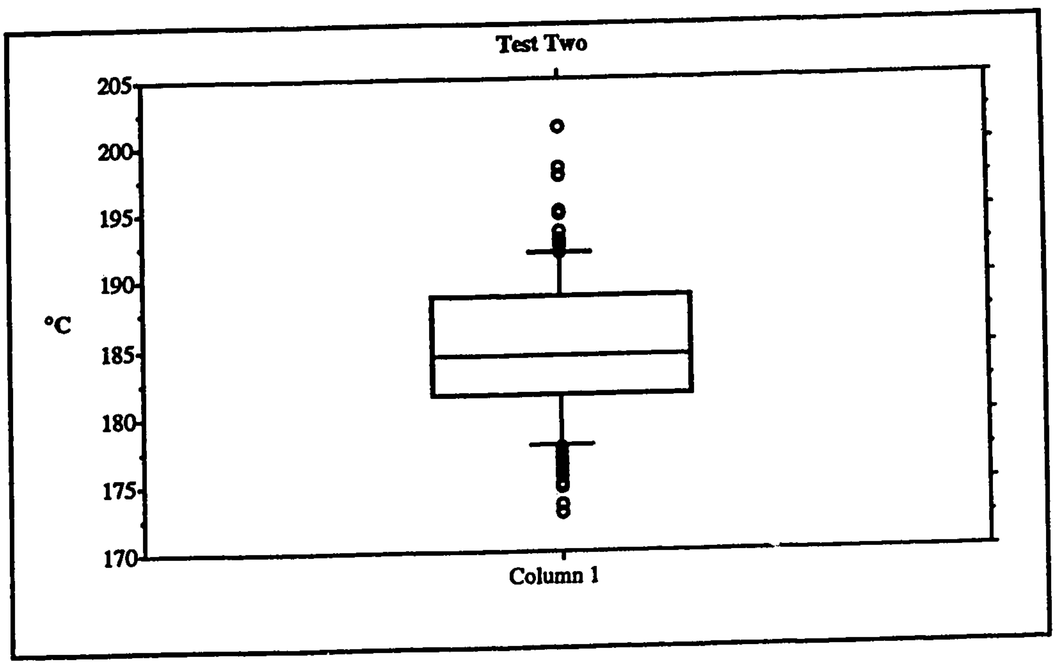
Mean	Group	Control	ETD(M)	D	ETD(C)	B
.0000	Control					
13.1250	ETD(M)					
48.4348	D	*	*			
51.7083	ETD(C)	*	*			
60.2917	B	*	*			

[redacted]

Operator:	CTL				
Sample	C 3.0	C 4.5	C 6.0	L	R
61	0.7	0.5	0.5	0.5	0.5
62	0.5	0.5	0.5	0.5	0.5
63	0.4	0.3	0.3	0.3	0.4
64	0.5	0.5	0.5	0.5	0.5
65	0.5	0.5	0.5	0.5	0.5
66	0.5	0.5	0.5	0.5	0.5
67	0.5	0.5	0.5	0.5	0.5
68	0.6	0.6	0.6	0.4	0.6
69	0.5	0.5	0.5	0.5	0.5
70	0.4	0.5	0.5	0.4	0.4
71	0.5	0.5	0.4	0.4	0.5
72	0.3	0.3	0.3	0.3	0.5
73	0.5	0.4	0.4	0.3	0.4
74	0.5	0.5	0.5	0.5	0.4
75	0.5	0.3	0.4	0.2	0.4
76	0.5	0.4	0.4	0.4	0.4
77	0.2	0.2	0.3	0.2	0.4
78	0.5	0.5	0.5	0.5	0.5
79	0.5	0.5	0.5	0.5	0.5
80	0.5	0.6	0.6	0.5	0.5

X1: Column 1

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
184.8407	5.441	.4683	29.6041	2.9436	135
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
172.8	201.3	28.5	24953.5	4616390.37	0



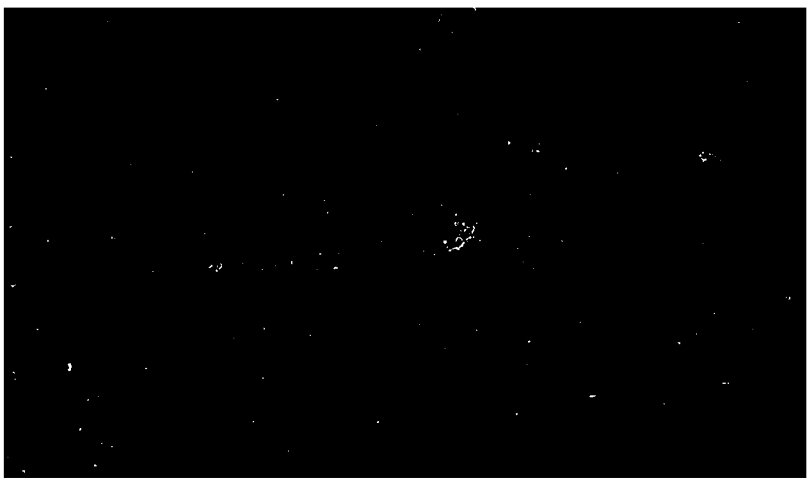
For Treatment Group "D"
VENDAM Veneer Damage

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1.0	8	34.8	34.8	34.8
	2.0	15	65.2	65.2	100.0
	Total	23	100.0	100.0	

Mean	1.652	Std err	.102	Median	2.000
Mode	2.000	Std dev	.487	Variance	.237
Kurtosis	-1.687	S E Kurt	.935	Skewness	-.684
S E Skew	.481	Range	1.000	Minimum	1.000
Maximum	2.000	Sum	38.000		

Valid cases 23 Missing cases 0

```
- - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - -
     Variable   TOOTHCO    ARI Tooth % CO
  By Variable   TREATGP    Treatment group

                                   ANALYSIS OF VARIANCE

                                    SUM OF          MEAN             F        F
        SOURCE            D.F.      SQUARES         SQUARES          RATIO    PROB

BETWEEN GROUPS              4     14673.0660      3668.2665       12.4389    .0000

WITHIN GROUPS             114     33618.0004       294.9026

TOTAL                     118     48291.0664

- - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - - - - - - -
     Variable   TOOTHCO    ARI Tooth % CO
  By Variable   TREATGP    Treatment group

MULTIPLE RANGE TEST

SCHEFFE PROCEDURE
RANGES FOR THE 0.050 LEVEL -

          4.43    4.43    4.43    4.43

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
      12.1430 * RANGE * DSQRT(1/N(I) + 1/N(J))

   (*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

                                C E E D B
                                o T T
                                n D D
                                t ( (
                                r M C
                                o ) )
                                l
     Mean        Group

      .0000      Control
     9.5000      ETD(M)
    17.9583      ETD(C)         *
    27.8696      D              * *
    29.3333      B              * *
```



[redacted]